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THESIS

THE USE OF AUSTENITIC STAINLESS STEEL
VERSUS MONEL (Ni-Cu) ALLOY
IN PRESSURIZED GASEOUS OXYGEN (GOX)
LIFE SUPPORT SYSTEMS

by

Bert Marsh

March 1985

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The Use of Austenitic Stainless Steel Versus Monel (Ni-Cu) Alloy in Pressurized Gaseous Oxygen (GOX) Life Support Systems

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ABSTRACT

Gaseous oxygen (GOX) must be stored at pressures up to 24 MPa (3500 psi) to provide the flow rates required to support the metabolic needs of a diver. A review of the literature concerned with materials compatibility in pressurized oxygen systems was conducted, with emphasis on metallic structural materials. Review of experimental and theoretical work on combustion of austenitic stainless steels and nickel-copper alloys revealed a consensus that Monel nominal (63% Ni - 34% Cu) is preferred in high pressure oxygen systems, when its strength and weight are acceptable. At the intermediate pressures, 0.7 to 10.3 MPa (100 to 1500 psi), the relative safety of stainless steel as a structural material is unclear. The testing methods reviewed were friction rubbing, particle impact, fresh metal exposure to heated flowing GOX, promoted ignition and resonance. An experimental apparatus was used to simulate the conditions of GOX flow found in an operational diving set and to compare the flame propagation rates for austenitic stainless steel (AISI 316), Monel (63% Ni - 34% Cu) and carbon steel (AMS 5050) tubing in this environment.

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I. INTRODUCTION

A diving system must store and deliver in metered quantities varying breathing mixtures to support the metabolic GOX requirement that underwater search salvage and construction place on a diver. The exact percentage of oxygen in the breathing gas mixture is determined by the intended mission and environmental conditions of a specific diving task. Mixtures range from 3% oxygen - 97% helium to 100% oxygen.

The respiratory minute volume (the product of the tidal volume of the human lung times the number of respirations per minute) gives a consumption rate for the oxygen. This rate may vary from 0.5 to 4.0 standard liters per minute (SLPM) depending on the exertion rate of the diver. When long distance swimming or deep ocean work is involved the high exertion levels combine with the restricted oxygen storage space availability to dictate that pressures in excess of 20.7 MPa (3000 psi) be used in the storage of oxygen. The higher pressure levels allow storage of the required volumes but result in material compatibility problems. Storage vessels, piping or tubing for delivery and pressure reduction and regulation equipment are required to be constructed of materials which are able to support large internal and external loads while providing corrosion resistance as well as resistance to ignition and combustion in an oxygen environment.

Catastrophic failures within an oxygen system often destroy the system (see Figure 2.1), thus limiting failure analysis. The impact of an oxygen system failure is at least the loss of oxygen supply to the diver with the possibility that a total conflagration will consume the diver, and/or the entire system. Such dire consequences and the difficulties experienced in determining the cause of an oxygen fire mandate careful design of all diving systems. Design criteria must include strict specification of the materials for the construction of the equipment. Only certain nonmetals and metals are recognized as being compatible with oxygen service.

This research was conducted as a review of the open literature. Information concerning the compatibility of metals with pressurized GOX was critically reviewed. Attempts to quantify the relative resistance of specific alloys to ignition and combustion were of special interest. The initial review revealed a lack of a uniform theory - one which can quantitatively cover all metals ignition and combustion processes and successfully rank metals for a variety of applications. The experimental evidence is confused and in many instances conflicting due in a large part to the myriad of testing procedures adopted. Markstein in 1963 [Ref. 1], found a lack of understanding of combustion in bulk metals due to a "relatively small research effort" and "certain distinct aspects of metal combustion." Presently, the lack of an integrated test procedure is responsible for the conflicting results found in the more recent research.

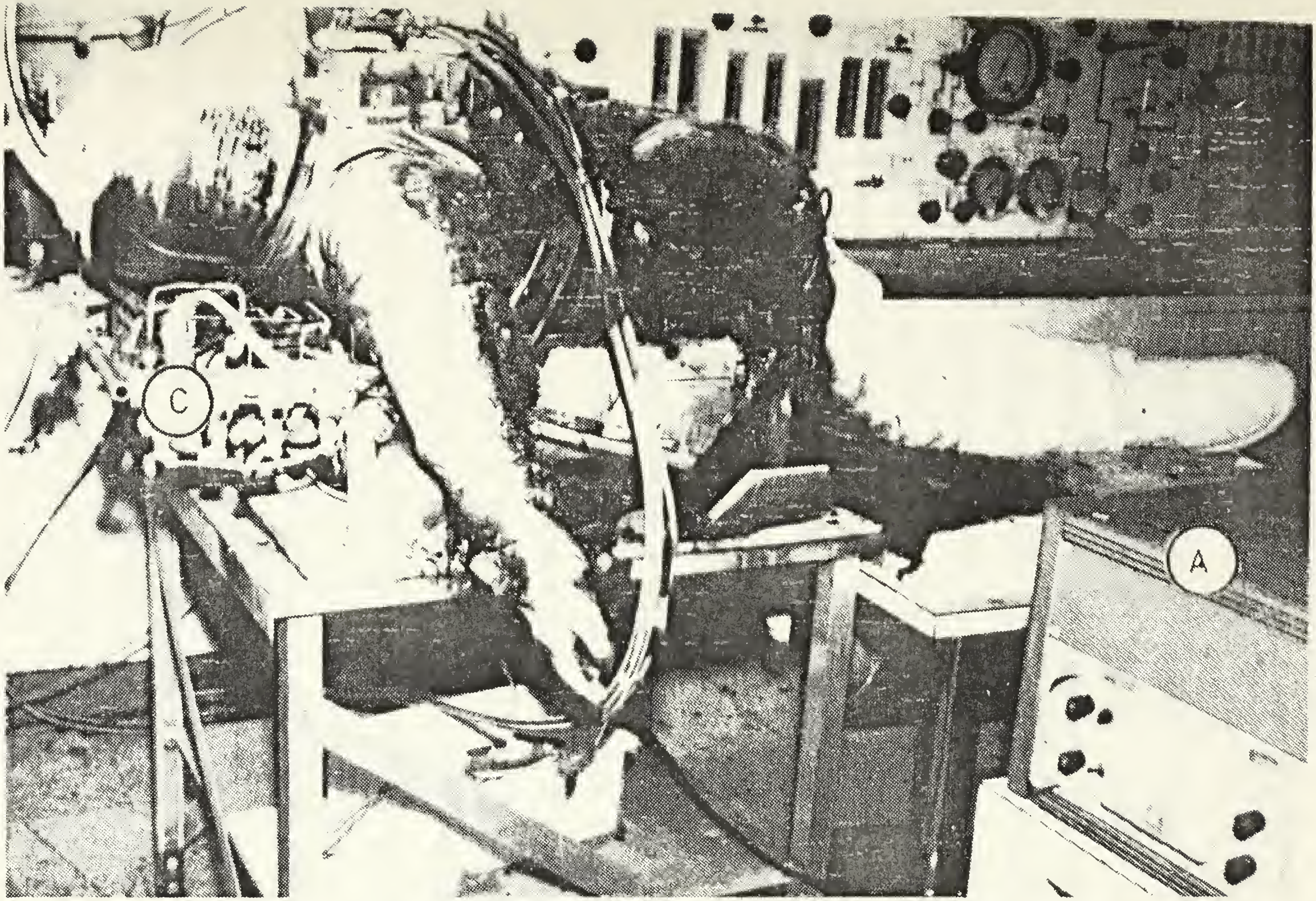

Figure 2.1. Drastic Results of a GOX Fire in a Space Suit.
Photo Courtesy of NASA White Sands.

This confusion about and the variance in the ordering of metals and alloys with respect to their ignition and combustion succeptibility, has resulted in a tendency to conduct specific testing of design configurations. A worst case scenario is devised and a safety factor applied to the testing conditions. This approach does not offer a theoretical solution which will effectively describe bulk metal ignition and combustion; rather it supplies an engineering acceptance criterion for one application.

Currently, the National Aeronautics and Space Administration (NASA), the National Bureau of Standards (NBS), the Japanese government and industry in addition to many independent researchers are attempting to develop a coherent theory of bulk metal ignition and combustion. From the literature surveyed, the majority of experimental procedures attempted were conducted in static pressure environments. Reports of burn rates for flowing systems are sparse. In this work, an experimental apparatus was used to simulate the flow conditions found in an operational diving set when ignition from an unknown source opens the interior of tubing carrying GOX under pressure to atmospheric pressure. A comparison was conducted of the propagation rates for combustion of the tubing in such a system for AISI 316 austenitic stainless steel, Monel (63% Ni - 34% Cu), and AMS 5050 carbon steel.

II. LITERATURE REVIEW

Early research into metal combustion was spurred by attempts to utilize the high level of energy released in the rapid oxidation of metals. The flashbulb, with its source of light being the combustion of a metal, was one of the first utilizations and was followed by research into the combustion of powdered metals as a source of high temperature flame. The advent of life support systems and the move to the use of propulsion oxidizers in the aerospace industry has continued the emphasis on research in the ignition and combustion processes of metals [Ref. 2].

Oxygen systems safety has been studied extensively by the U.S. Bureau of Mines since 1923. Abroad guidelines on the use of steel pipelines in compressed gas applications including oxygen systems were issued by the Reichminister of Industry and the Reichminister of Labor in Germany in 1942, which demonstrates the long standing concern with oxygen system safety [Ref. 3].

More recently, the Defence Metals Information Center [Ref. 4], the National Aeronautics and Space Administration, [Ref. 5], and the Department of Energy [Ref. 6], have commissioned extensive literature reviews and sponsored additional research into the ignition and combustion of metals in oxygen environments.

The U.S. Navy has commissioned two recent reviews - one by Purcell and Kreidt in 1969, and one by Hersh in 1974 - in addition to sponsoring investigations into several oxygen fires, all with a primary goal of defining the compatibility of metals with oxygen service.

A. RANKING OF METALS

All literature reviews conclude that there is confusion as to the ranking of metals with respect to their compatibility with oxygen. An example of the confusion is shown in Table I which compares the results of earlier (unpublished) work done at Linde with the work done by Dean and Thompson [Ref. 8]. Note the reversal of the respective position of Aluminum. Dean and Thompson rank Aluminum at the top of their list (most resistant), while in the promoted ignition tests at 13.8 MPa (2000 psi) Aluminum was ranked as the least resistant to ignition and combusion. Nihart and Smith, in reporting their experimental results (see Table II) have developed their own ranking of metals in order of resistance to ignition and combustion.

The difference in ranking of various metals between Dean and Thompson's[1] and Nihart and Smith's test results can be attributed to the differences in methods and objectives of their respective research. Nihart and Smith were concerned

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[1] Dean and Thompson do not specifically rank their results in tabular form but instead present graphical data and draw conclusions from the graphs.

TABLE I

Relative Ranking of the Resistance of Metals and Alloys To Ignition and Combustion Based on Different Authors and Test Methods; Reproduced from Nihart and Smith [Ref. 9]

Dean and Thompson (3)	Velocity Impact	Promoted Ignition
50-800 psi	50-100 psi	2000 ps'
Aluminum	**Monel	**Monel
Nickel A	**K-Monel	**Inconel 600
*Hastelloy C	***Tobin bronze	**Monel S
**Monel	Copper	***Tobin bronze
*Hastelloy X	Steel	**Duranickel
**Inconel X	18-8 stainless steel	*****Ampco alloy No. 15
*Hastelloy R	Aluminum	**Permanickel
Copper		**K-monel
*Haynes 25		*Hastelloy R-235
*Multimet		Maraging Steel
18-8 Stainless Steel		Beryllium Copper
Other Stainless Steel		******Elgiloy
Carbon Steel		****Rene' 41
Titanium		**Inconel X-750
		*Multimet
		*Hastelloy X
		*Haynes 25
		***Everdur
		18-8 Stainless Steel
		Aluminum

TRADEMARKS

*Union Carbide Corporation, Stellite Division
**The International Nickel Company, Inc.
***Anaconda American Brass Company
****General Electric Company
*****Ampco Metal, Inc.
******Elgin National Watch Company

TABLE II

Results of Nihart and Smith [Ref. 9] Promoted Ignition Tests Conducted in a Static 7500 psi Oxygen Environment

Metal or Alloy	Weight of Neoprene to Completely Combust Standard Specimen 5 mm x 30 mm x 0.005"
Gold	Only melts
Silver	Only melts
Nickel	48 to 56 mg
Monel alloy 400	18 to 19 mg
Yellow Brass (partial combustion only)	11.8 to 15.2 mg
Inconel alloy 600	13.2 mg
Aluminum	11.0 to 16.4 mg
Copper	10.5 mg
Inconel alloy X-750	9.0 mg
Stainless Steels	7.1 to 8.5 mg

Estimated from results of a number of tests which were either standard with only part of the specimen consumed or were not standard and either complete or partial combustion occurred.

with the possible ignition of a storage system that would maintain a 51.7 MPa (7500 psi) internal pressure of GOX. They considered several testing methods, finally deciding on a promoted ignition test within a combustion bomb charged to a static internal oxygen pressure of 51.7 MPa (7500 psi). Dean and Thompson were concerned with a rocket motor combustion chamber where structural metals would experience extended periods of exposure to high temperatures. Their method of testing involved resistance heating of different metal tubing types in a flowing system, which had various gas mixtures flowing over the exterior of the test specimens. A detailed analysis of the differences in these results can be found in Ref. 7.

The significance of the variation in the ranking of metals within these two research efforts is simply that the method of testing was decided upon with a specific configuration in mind. An inherent problem in much of the reported work is the tendency to conduct tests which will quantify compatibility of specific metals for an intended application, which often precludes comparison of results.

An additional contributing problem with research into metals compatibility with oxygen is the tendency for proprietary rights to discourage open publication of commercially-backed research.

B. METHOD OF IGNITION

The chemical kinetics and the mode of heat transfer of the rapid oxidation products are dependent on the method by which energy is added to the system. The experimental procedures used in studying metal ignition reflect the variety, and individual investigators evaluation of the significance of a specific ignition source. It is useful to review results within the appropriate category of ignition sources. This associates research which shares the same basic assumptions. A listing of the major categories of ignition sources considered in this review is given in Table III.

TABLE III

SOURCES OF IGNITION ENERGY

1. Kinetic Energy of Gas or Entrained Particles
2. Friction
3. Foreign Material/Softgoods Ignition
4. Resistance (Joule) Heating
5. Resonance
6. Mechanical Impact

Table III is not as comprehensive as that produced by Benz [Ref. 15] and Stolfzfus,[2] but it does encompass the methods chosen by a steering committee that is currently directing research into the ignitability of metals in oxygen.

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[2] See Table VII.

C. RESEARCH RESULTS GROUPED BY THEIR IGNITION SOURCES

1. Kinetic Energy of Gas or Entrained Particles

The early work of Nihart and Smith [Ref. 9] included testing of the possibility of heating the entrained GOX in a system via adiabatic compression of the gas. An example of adiabatic compression would be the result of the rapid opening of a valve with a large pressure differential between the up-stream and downstream sections with the downstream section dead-ended. Theoretical calculation of the temperature rise that would accompany a very rapid compression is based on the assumption that GOX behaves like a perfect gas. Therefore, Equation 3.1 should predict the temperature rise of the gas in a piping system that experiences a rapid compression.

$$T_2/T_1 = (P_2/P_1)^{N-1/N} \qquad \text{(eqn 3.1)}$$

The temperatures which are theoretically obtainable are graphed in Figure 3.1. For a sudden rise in pressure from ambient to 48.2 MPa (7000 psi) the temperature predicted would be above 1400^{o}C, which is at or above the predicted ignition temperatures of several metals when they are exposed to pure oxygen at high pressures. Nihart and Smith intended to test the ability of adiabatic compression to raise the temperature of metals to their ignition points. However, in preliminary testing which involved pressurizing a 1.3 m (51 inch) section of 0.8 cm (5/16 inch) diameter pipe from ambient pressure to 45.8 MPa (6650 psi) the maximum temperature

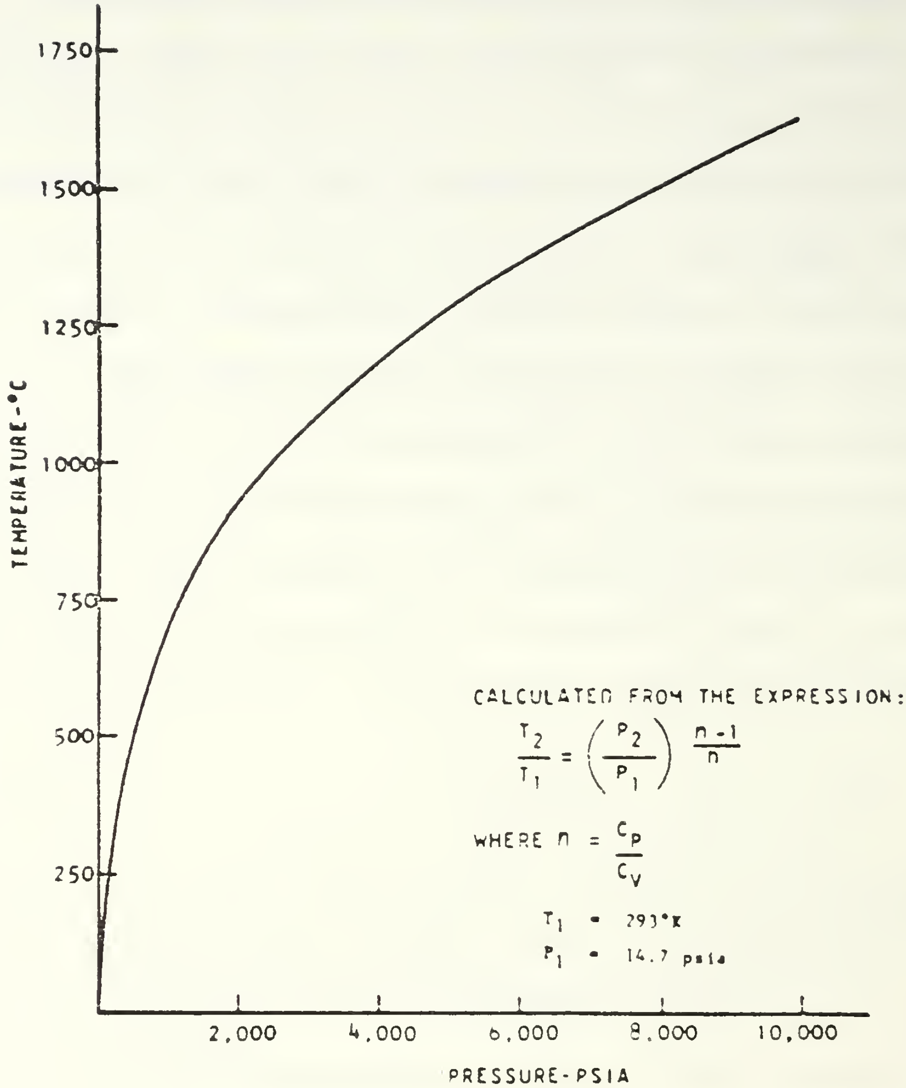

Figure 3.1. Theoretical Temperature Attained by Adiabatic Compression Taken from [Ref. 9]

attained was 378°C, approximately 1/3 of the theoretical prediction. The assumption of an adiabatic compression and the treatment of oxygen as a perfect gas, which does not change its specific heat in rapid compression, was an over

simplification. The mixing of the compressing gas with the gas in the pipe prior to compression and the changing value of the specific heat of oxygen with pressure invalidate the assumption of dieseling (rapid adiabatic compression) as a source of temperatures in the range that would ignite metals. The temperatures attainable are well within the range which would ignite nonmetal components as Nihart and Smith found in testing Kel-F81, Viton A and virgin Teflon (all commonly found softgoods in oxygen systems). Therefore, dieseling is not a direct ignition hazard to metals but may ignite components of an oxygen system and lead to the rupture of the structural metal and possible ignition. [Ref. 9]

Most researchers recommendation, that any valve installed in an oxygen system be "slow acting" is a conscious safety precaution that is accepted by all military and civilian designers and operators of pressurized oxygen systems. It is valid and necessary and should be incorporated into any design manual or operating procedure established by any diving authority.

deJessy [Ref. 10] addressed the affect of a change in the specific heat of oxygen and concluded that dieseling was a source of ignition of softgoods or contaminates only. His research effort then centered on the possible temperature rise in piping due to particle abrasion or impact. To test the possibility that particle abrasion could produce temperatures which could ignite metals deJessey developed an

initial trial section which included a large spiral followed by a plexiglass chamber. By injecting carbon steel balls individually (each one 0.8 mm in diameter) and accelerating them with the GOX flow their temperature rise could be measured by the color they exhibited while passing through the plexiglass chamber. At speeds of 300 m/s (1000 ft/s) the carbon steel balls where seen to glow red hot. This result encouraged the construction of a more elaborate test rig with multiple bends, tees, and small radius (2.5 x diameter) curves. The testing was all done on carbon steel pipe as the research was aimed at determining the maximum flow velocity which would be acceptable in long distance GOX pipelines passing from one industrial center to another through the French countryside. deJessy was only able to ignite carbon steel pipe of diameter 3.0 cm (1.2 inches) with steel cuttings as the particles injected. He concluded that there was no direct danger from particle abrasion as the normal construction and maintenance of oxygen pipelines should eliminate all contaminates that would be capable of ignition themselves or of igniting the steel pipeline. Industrial experience suggested to deJessy that care in installation and an inert gas flush prior to the first use of the pipeline would render carbon steel pipelines safe for a velocity up to 60 m/s (180 ft/s), a conservative maximum. [Ref. 10]

In the middle 1960's German industrial pipelines were built and used under the earlier cited regulations, which

restricted the velocity of GOX in carbon steel pipelines to 8 m/s (26 ft/s). Wegener [Ref. 3] conducted numerous experiments simulating the introduction of contaminate particles into a flowing stream of GOX where restrictions and short radius bends would result in heating due to friction and impingement. The apparatus utilized by Wegener allowed the injection of particles of contaminates into long (40m) trial sections via a bypass section which could be isolated and loaded with 1-3 kg of the solid contaminate. This experiment was conducted using mass introduction of contaminate vice the single particle injection technique. Control of the inlet pressures and the velocity of the GOX at the inlet allowed repeated trials with a variety of contaminates that varied from nonorganic sand to coke and stone coal. The results of Wegener's work can be seen in Figures 3.2 and 3.3.

The inorganic solids were safe at pressures up to 28 ATM (412 psi) and a velocity of 53 m/s (174 ft/s). With welding cinder and coke, ignition of the entrained particles occurred at a velocity as low as 13 m/s (42.9 ft/s). This result stresses the importance of flushing an installation of pipe with inert gas prior to placing it into service.

Wegener was unable to predict precisely the energy input into the system as turbulent flow and mass injection of the contaminate precluded the direct calculation of the kinetic energy of each particle. The measurement of the energy input which produces an ignition is critical in the

Test conditions and results with straightline trial section.

Added Solids	Flow velocity w and press. p. of oxygen at start (index 1) and at end (index 2) ω_1 In m/s	ρ_1 In ata	ω_1 In m/s	ρ_1 In ata	No. of tests and Results[1)]
sand	18	28	19	27	1-
	33	26	37	23	2-
	51	27	84	16	3-
rust	33	25	37	22	2-
	44	28	57	22	2-
	51	27	84	16	2-
fluedust accumul.	29 bis 33	25	33 bis 37	22	2-
	44	28	57	22	2-
	51	27	84	16	2-
mill cinder	33	25	37	22	1-
	44	28	57	22	2-
	51	27	84	16	2-
welding cinder	33	25	37	22	1-
	41	29	57	23	2+
	51	27	84	16	2-
coke	29 bis 33	25	33 bis 37	22	2-, 1+
	44	29	57	23	2+
	51	27	84	16	3+
stone coal	11	29	11	29	1-
	13	22 bis 29	13	22 bis 29	3-, 1+
	18	20 bis 20	19	19 bis 28	4+

1) + = sparks observed, - = no sparks observed.

Figure 3.2. Wegeners Results for Straight-Line Trial Sections. Taken from [Ref. 3]

Added Solids	Flow velocity w and press. p. of oxygen at start (index 1) and at end (index 2) ω_1 In m/s	ρ_1 In ata	ω_1 In m/s	ρ_1 In ata	No. of tests and results
sand	30 bis 32	28 bis 29	3 bis 36	25 bis 26	4–
	43 bis 44	25bis 28	55 bis 57	21 bis 22	3–
	52	28 bis 29	82	18	12–
rust	30 bis 32	28 bis 29	33 bis 36	25 bis 26	5–
	40 bis 44	25 bis 28	55 bis 57	21 bis 22	3–
	52 bis 53	27 bis 29	82 bis 85	17 bis 18	18–
fluedust	30 bis 32	28 bis 29	33 bis 36	25 bis 26	4–
accumulated	43 bis 44	25 bis 28	55 bis 57	21 bis 22	3–
	52 bis 53	29 bis 29	82 bis 85	17 bis 18	16–
millcinder	29 bis 32	28 bis 29	30 bis 36	25 bis 26	11–, 2+
	42 bis 44	27 bis 29	55 bis 57	21 bis 22	5–, 9+
	52	29	82	18	3–, 9+
	52	29	82	18	fire after 1. elbow
weldingcinder	13	29	13		2–
	17	29	18	28	2+
	28	29	31	26	6–, 4+
	42 bis 44	27 bis 29	55 bis 57	21 bis 22	1–, 5+
	50 bis 33	28 bis 29	82 bis 85	17 bis 18	2–, 13+
submerged arc	42 bis 44	27 bis 29	53 bis 57	21 bis 22	3–, 3+
welding slag	50 bis 52	27 bis 29	82 bis 83	17 bis 18	9–, 1+
coke	17	29	18	28	2–, 1+
	30 bis 32	28 bis 29	33 bis 36	25 bis 26	5+
	42 bis 44	27 bis 29	55 bis 57	21 bis 22	18+
	52 bis 53	27 bis 28	82 bis 85	17 bis 18	13+
	53	29	85	18	fire after 4. elbow
stone coal	13	29	13	29	2–
	13	29	13	29	fire on several spots
	32	29	36	26	fire after 2. elbow
mixture of 20%	13	29	13	29	2+
iron powder and	23	29	31	26	1–, 2+
80% sand	28	29	31	26	fire after 3. elbow
	42	29	55	22	fire after 3. elbow

1) + = sparks observed, – = no sparks observed

Figure 3.3. Wegeners Results for Curved Line Trial Section. Taken from [Ref. 3]

development of a theoretical solution. Thus, mass particle injection may simulate possible conditions in an operating systems but it does not lend itself to a theoretical treatment of bulk metal ignition.[3]

Heinicke recorded similar results to those of Wegener [Ref. 11], utilizing curved test sections. He observed no reaction from inorganic contaminates but spark and fire production in powdered iron and mill cinder test (see Figure 3.4).

Heinicke defines tribomechanical stress as producing a state of lattice distortion which allows rapid oxidation and an "ensemble effect", which in turn produces temperatures capable of igniting steel pipe. This result is based on earlier work by Heinicke [Ref. 12] where he reports a change in the activation energy of iron in oxidation by oxygen from 0.16 Kcal/mol when a tribochemical reaction was present versus the standard value of 13 Kcal/mol under normal nonfrictionally stressed conditions. [Ref. 11]

As a result of his investigations Heinicke recommended that an inert gas flush may not be complete enough when a GOX production facility is started up for the first time; rather the combination of an inert gas flush followed by a mixture of 10% oxygen and an inert gas should be used.

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[3]Wegener experienced several blowouts/fires which always occurred after an elbow but he did not see combustion progressing in the opposite direction to the flow.

Added solid Material	speed range m/s	pressure range	No. of tests results + sparks - no sparks
sand	30 - 36	25 - 29	4 -
	43 - 57	21 - 28	3 -
	52 - 82	18 - 29	12-
Mixt. of	13	29	2 +
80% sand	28 - 34	26 - 29	1 -, 2+
20% powd. iron	28 - 34	26 - 29	Fire
	42 - 56	22 - 29	Fire
Mill Cinders	28 - 36	26 - 29	11 - , 2 +
	42 - 57	22 - 27	5 - , 9 +
	52 - 82	18 - 29	3 - , 4 +
	52 - 82	18 - 29	Fire

Figure 3.4. Results of Heinicke and Harenz Taken from [Ref. 11]

Bates and Monroe et. al. [Ref. 6] at the Southern Research Institute were commissioned by the Department of Energy to study the feasibility of and the material compatibility problems involved in producing compressors for high BTU gas production from coal. This process requires large volumes of GOX at 68 to 102 atm (1000 to 1500 psig). Large in this context can mean 28 to 57 standard cubic meters per second (SCMS) (60,000 to 120,00) SCFM). The internal conditions expected within such a compressor were estimated at the extreme to be 68 atm (1000 psig) with GOX at 149-260^{O}C (300-500^{O}F) and a gas velocity of MACH 0.7 to 0.8.

One test conducted was a single particle impact test using 0.016 cm (0.04 inch) diameter silicon beads as the projectiles. Individual particles travelling at 427 m/s (1400 fps) in GOX with an internal pressure of 68 atm (1000 psig) striking gauge/notched specimens with 0.03/0.024 cm (0.08/0.06 inch) diameters, which were preheated to temperatures up to 824^{O}C (1550^{O}F), were used to test the materials listed in Table IV. With one exception, a single sample of

TABLE IV

List of Materials Tested for Impact Sensitivity

1. Carbon Steel AISI 1025
2. AISI 4140
3. Ductile Iron
4. 304 Stainless Steel
5. 17-4 PH Stainless Steel
6. 410 Stainless Steel
7. Lead Babbit
8. Tin Babbit
9. Inconel 718
10. Aluminum 1100

AISI 4140 steel, all the results were negative (no ignitions). The single exception was with a sample of 4140 steel which was preheated to 638°C (1180°F); however, Bates and Monroe were unable to duplicate this result [Ref. 6].

Testing of various geometries such as thin wire, tubing, or samples shaped in the form of a notched tensile test sample, has been conducted in varying pressures of heated gas in both static and flowing conditions. The results of these tests are inconclusive. The build-up of an oxide layer which (in most structural metals used in GOX compressor construction) is responsible for an increase in the ignition temperature of the metal means that flow of GOX over a metallic surface may increase its safety by raising its ignition temperature. However, should the protective oxide layer be disturbed by penetration, cracking or spalling its protective capability will vanish, in fact with the flow of oxygen rapid oxidation is promoted on such a fresh surface. This reversal of the nature of the oxide layer lead Bates and Monroe to test specimens of commonly used metals in a flowing GOX system under fresh exposure conditions. A schematic drawing of the test apparatus can be seen in Figure 3.5.

Bates' and Monroe's testing procedure was based on the assumption that within an oxygen compressor exposure of fresh surface to GOX at elevated temperatures and velocities up to Mach 0.85 presents a serious ignition hazard. From Figure 3.5 the design of the test cell shows that a torsional

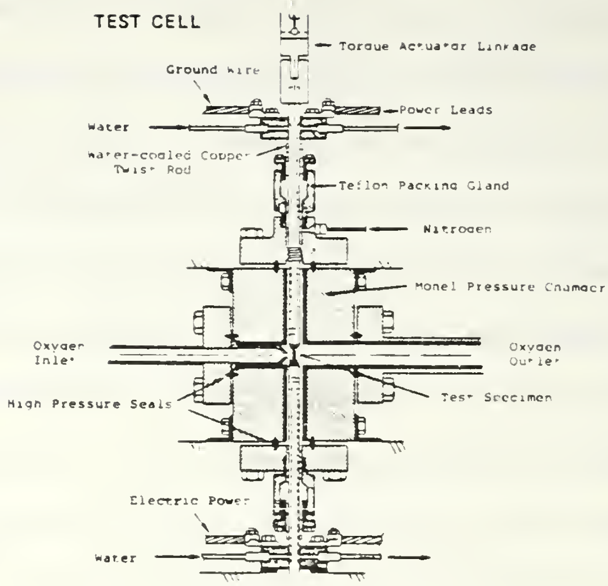

Figure 3.5. Schematic Sectional View of High Pressure Oxygen Test Cell. Taken from [Ref. 6]

stress applied by rotating the grips would break and expose the specimen to the preset temperature, pressure and velocities of flowing GOX. In addition the power supply of electrical current through the test specimen allowed resistance heating of the specimen. Their test matrix was extensive including all the alloys of Table IV while varying the GOX temperature, the specimen temperature and the gauge size of the specimens. All of the specimens were freshly exposed by a break due to torsional stress. Results for AISI 304 Stainless Steel are comparable to those of Monel 400 as can be seen in Tables V and VI.

TABLE V

Effects of Temperature and Fresh Metal Exposure on Ignition and Burn Behavior of 304 Stainless Steel, AISI 304

Taken from [Ref. 6]

Specimen Number	Temperature, °F		Specimen Diameter Gauge/Notch, In.	Ignition or Burn
	Oxygen	Specimen		
A92	400	519	.80/.060	No ignition
B5	300	500	.80/.060	No ignition
B61	300	500	.060/.045	No ignition
B611	300	500	.060/.045	No ignition
B71	300	500	.040/.030	No ignition
B711	300	500	.040/.030	No ignition
A90	430	1030	.080/.060	Half gauge burned, quenced at shank
A91	400	1095	.080/.060	Half gauge burned, quenced at shank
B81	320	1000	.060/.045	Consumed part of gauge
B811	310	1000	.060/.045	Consumed gauge
B91	310	1000	.040/.030	Consumed part of gauge
B911	330	1000	.040/.030	Consumed part of gauge

TABLE VI

Effects of Temperature and Fresh Metal Exposure on Ignition and Burn Behavior of Monel 400 Taken from [Ref. 6]

Specimen Number	Temperature, °F Oxygen	Temperature, °F Specimen	Specimen Diameter Gauge/Notch, In.	Ignition or Burn
A85	310	500	.080/.060	Localized ignition and quench
A86	380	1500	.080/.060	Ignition, local burn, self-quench
A153I	310	1000	.080/.060	Ignition and quench
A153II	325	1500	.080/.060	Ignition, local burn, quench
A1541	325	1500	.060/.045	Local burn and quench
A1541II	300	1500	.060/.045	Local burn and quench
A155I	330	1000	.060/.045	Ignition and quench
A155II	325	1000	.060/.045	Ignition and quench
A156I	330	1000	.060/.045	Ignition and quench
A156II	300	1000	.040/.030	Ignition and local burn, self-quench
B49II	310	500	.040/.030	No ignition
B49III	300	500	.040/.030	No ignition
B49I	320	500	.040/.030	No ignition
B109I	300	500	.080/.060	Ignition and quench
B109II	300	500	.080/.060	Ignition and quench
B109III	300	500	.060/.045	Ignition and quench
B109IV	300	500	.060/.045	No ignition

The Monel ignited in several tests with the specimen temperatures at or below 538°C (1000°F) for several gauge sizes, in fact, Table VI records ignitions of Monel 400 at specimen temperatures as low as 260°C (500°F), while Table V shows no ignition of AISI 304 with any specimen temperature below 538°C (1000°F)[4].

To assume that AISI 304 is superior based on these results is inappropriate as the importance of the labels <u>ignition and quench</u> and <u>ignition and burn</u> is not clearly defined in the table legends but the difference is significant in Bates and Monroe's opinion. By extensive testing of AISI 304 as shown in their results (see Figure 3.6), Bates and Monroe develop an envelope of safe operations which would encompass a GOX compression process. Within the parameters that describe the compression of GOX from ambient pressure to 68 ATM (1500 psig) a margin of safety for AISI 304 can be found[5]. For AISI 304 the safety margin at 2.6 MPa (385 psi) was 260°C (500°F) at 5.2 MPa (750 psi) the safety margin was 149°C (300°F) and at 6.9 MPa (1000 psi) it was 121°C (250°F). In comparison

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[4]The oxygen parameters, internal pressure and velocity of the GOX are identical in Tables V and VI.

[5]Bates defines the safety margin as "the difference between the nominal compressor operating temperature and the temperature above which a given material will burn after ignition in an oxygen atmosphere at the stage pressure".

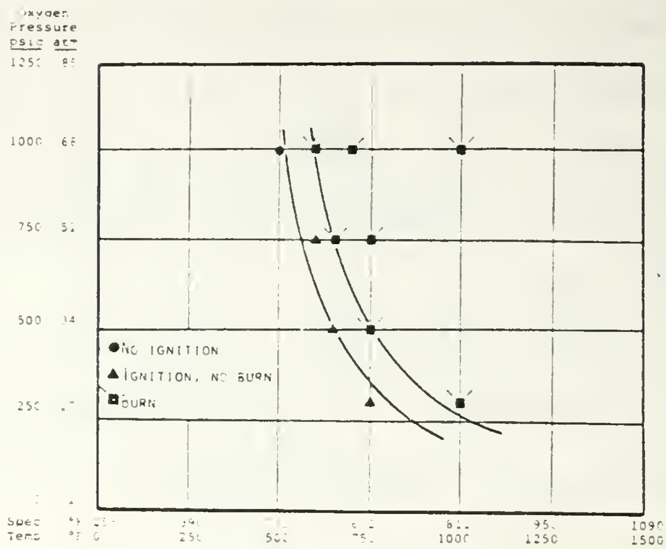

Figure 3.6. Effects of Pressure, Temperature, and Fresh Mean Exposure on Burning of 304 Stainless Steel. Specimen size: 1.03/ 1.52 mm (0.080/0.060 in.) Taken from [Ref. 6]

Bates and Monroe were unable to ignite and burn Monel 400 which places its safety margin in excess of $538^{\circ}C$ ($1000^{\circ}F$)[6].

In more recent research NASA White Sands Test Facility (WSTF) tested a Flow Control Valve (FCV) for the Space Shuttle's main propulsion system. The FCV were identified as being at high risk due to several factors: repetitive exposures; the Aluminum construction of the external oxygen tank; poor filtration (large size 800 micron filters); and high flow rates of

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[6] Bates and Monroe were concerned with the possible ignition by electrical spark acrossed the broken specimen, however, they were unable to quantify its effect on ignition.

GOX. The FCV shown schematically as Figure 3.7 has two flow paths, one through a bypass orifice for continuous flow and a second flow path controlled by a solenoid-operated poppet which provides a controlled flow. From this configuration it was determined that both subsonic and sonic velocities of GOX could entrain particles and impact valve body surfaces, thus testing was done in three configurations. A high velocity configuration simulating conditions at the bypass and control orifice, a low velocity configuration simulating subsonic conditions and an impact tube design which simulated the conditions found in a 30-degree angle outlet from the bypass in the FCV into the outlet tube, were all constructed. [Ref. 13]

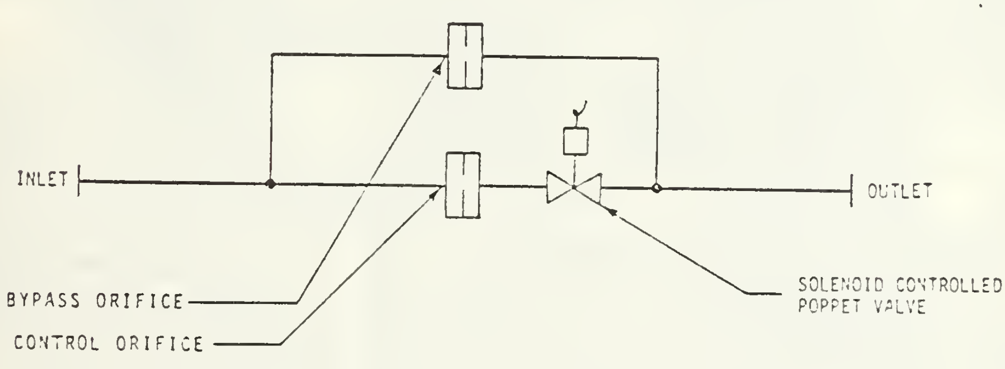


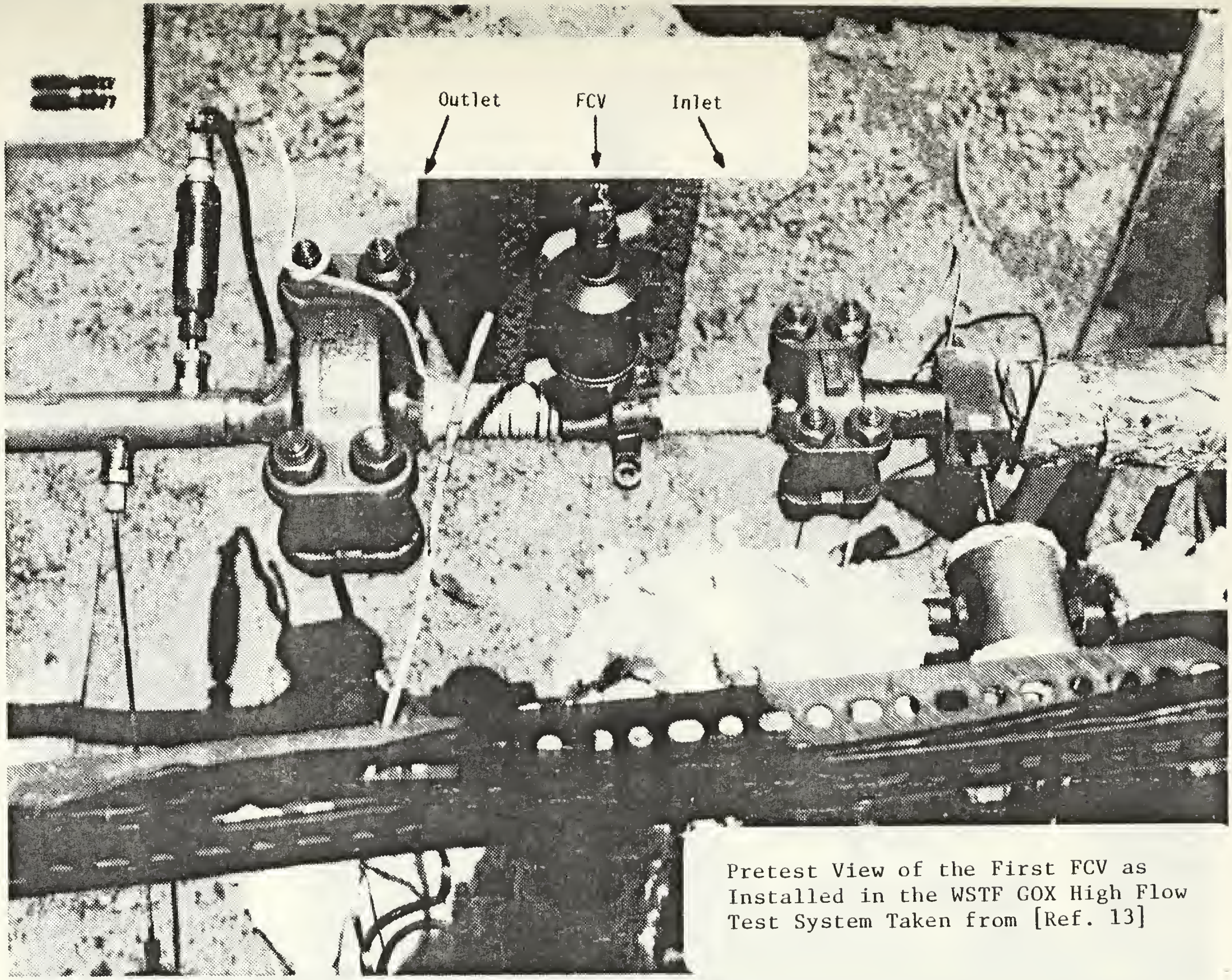
Figure 3.7. Simplified Schematic of Shutte Main Propulsion System Oxygen Flow Control Valve (FCV) Taken from [Ref. 13]

Initial testing of the FCV shown in Figure 3.8 and Figure 3.9 resulted in ignition and combustion of the FCV. Single 800 micron particles were inserted while the test article temperature was maintained at 204-277^{o}C (400-530^{o}F) and the internal line pressure was maintained at 28-35 MPa (4000-5000 psi). Up to the 12th particle no reaction occurred but upon injection of the 13th particle the result was a total failure at the FCV. Porter et. al. [Ref. 13] then continued to test alternative metals utilizing the high and low velocity test configurations with 1 mg samples of 150 micron size particles of 2024 Aluminum and Inconel 718 in addition to individual 800 micron 2219 Aluminum particles as the projectiles. Monel proved superior as Porter was unable to ignite Monel, but was able to ignite AISI 304L CRES with 800 micron 2219 Aluminum particles in the high velocity test appratus (see Figure 3.10).

2. Friction

Tribology has been studied as a method of ignition for centuries and has been the subject of numerous investigations into metals compatibility with GOX. In more recent work experimental results and theoretical prediction have been compared.

Jenny and Wyssmann [Ref. 14] conducted friction rubbing experiments with the intent of ranking materials for GOX compressor applications. They were specifically concerned with GGG 40 (ASTM A 536), nodular cast iron,x20Cr13 (AISI 403) stainless steel, CuSn10 Tin Bronze and Monel K500 (63% Ni-30% Cu)



Pretest View of the First FCV as Installed in the WSTF GOX High Flow Test System Taken from [Ref. 13]

Figure 3.8. Pretest Configuration of FCV.

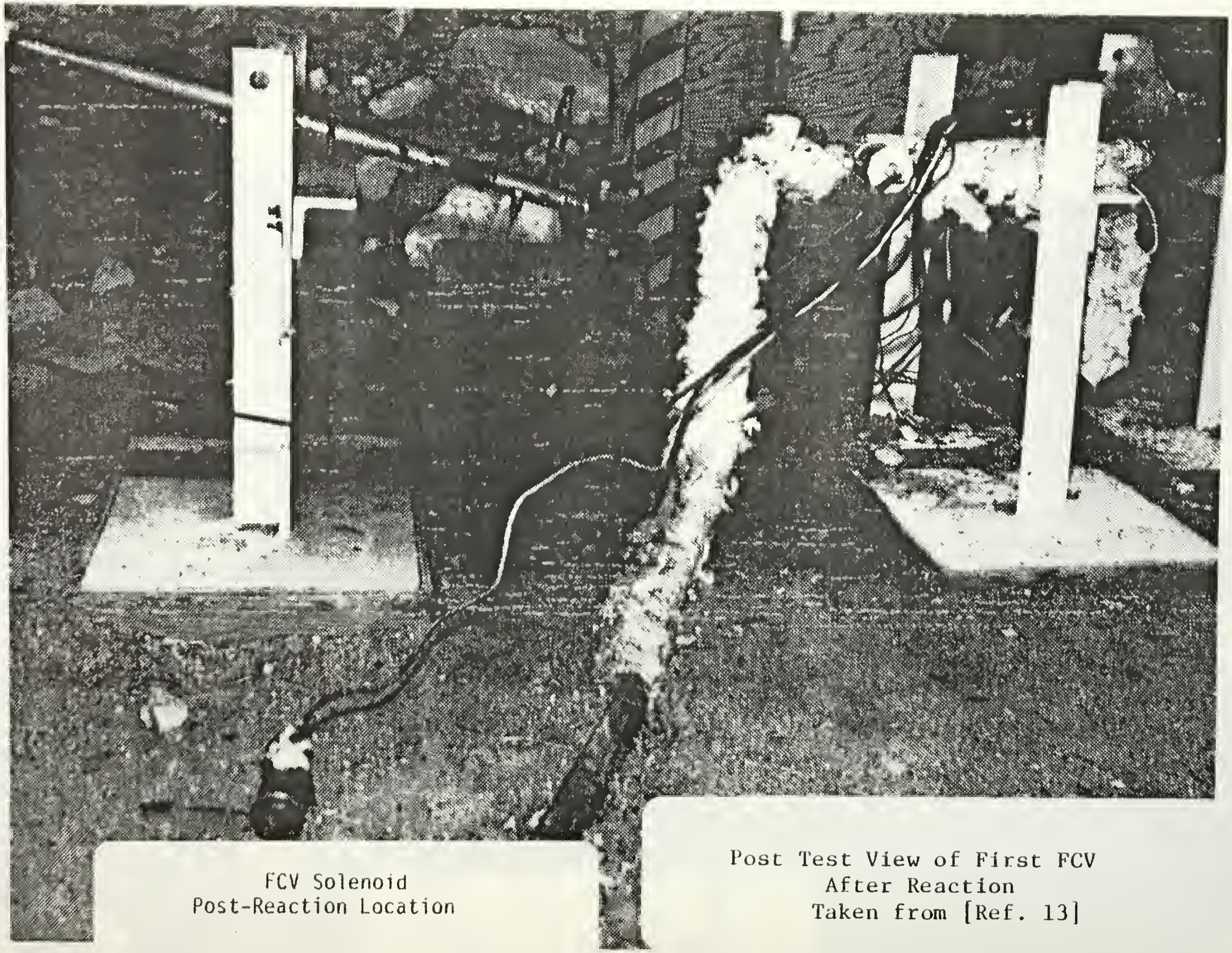


Figure 3.9. Post Test Position of FCV.

SUMMARY OF PARTICLE IMPACT TEST RESULTS

IMPACT PLATE MATERIAL	PARTICLE MATERIAL	PARTICLE SIZE (microns)	PARTICLE QNTY	ORIFICE MATERIAL	NOMINAL INLET CONDITIONS PRESS RANGE (psia)	NOMINAL INLET CONDITIONS TEMP RANGE (^oF)	WSTF IMPACT FIXTURE	TEST RESULTS REACTIONS/TEST/LOCATION		
Monel 400	2219 Alum	800	2 PTC	Monel	4570	530	High velocity	0	1	
Monel 400	2219 Alum	800	5 PTC	Monel	4390-4500	538	High Velocity	0	2	
Monel 400	2219 Alum	800	10 PTC	Monel	4050-4310	566-580	High Velocity	0	5	
104L CRES	2024 Alum	150	1 mg	Monel	3950-5000	476-534	Low Velocity	0	20	
104L CRES	Inconel 718	150	1 mg	Monel	3800-4950	513-537	Low Velocity	0	20	
104L CRES	2219 Alum	800	1 PTC	304 CRES	3200-3500	520	High Velocity	2	2	Impact Plate

Figure 3.10. Impact Results on Alternate Metals. Taken from [Ref. 13]

Within their test arrangement (see Figure 3.11) axial thrust force could be varied from 300 to 2100 Newtons (N) and the flow of gas through and around the interface could be changed from Nitrogen to GOX at the a constant flow rate of 0.01 m^3/s. Jenny and Wyssmann reported no significant difference in their results at 6,000 RPM or 12,000 RPM which lead them to maintain a constant 8520 RPM or an average sliding velocity of 3.8 m/s.

Utilizing Equation 3.2 as a model for the energy input by oxidation per unit area and Equation 3.3 to represent the frictional energy input, while describing the temperature field in the specimen by Equation 3.4, Jenny and Wyssmann were able to determine the oxidation energy through performing "practically identical" tests with inert (N_2) gas and GOX.

$$\dot{q}_{ox} = H\ A\ \exp\ (-E/RT) \qquad \text{(eqn 3.2)}$$

$$\dot{Q}_f = \mu(T)\ L\ u \qquad \text{(eqn 3.3)}$$

$$\partial T/\partial T = a\ \Delta\ T \qquad \text{(eqn 3.4)}$$

H = Heat of reaction of metal and oxide

E = Activation energy of metal

A = Rate factor dependent on rate controlling process

R = Universal gas constant

T = Temperature (Kelvin)

$\dot{q}$ = Energy rate per unit surface area

$\dot{Q}$ = Energy rate

$\mu(T)$ = Coefficient of friction, function of temperature

L = Axial force in Newtons

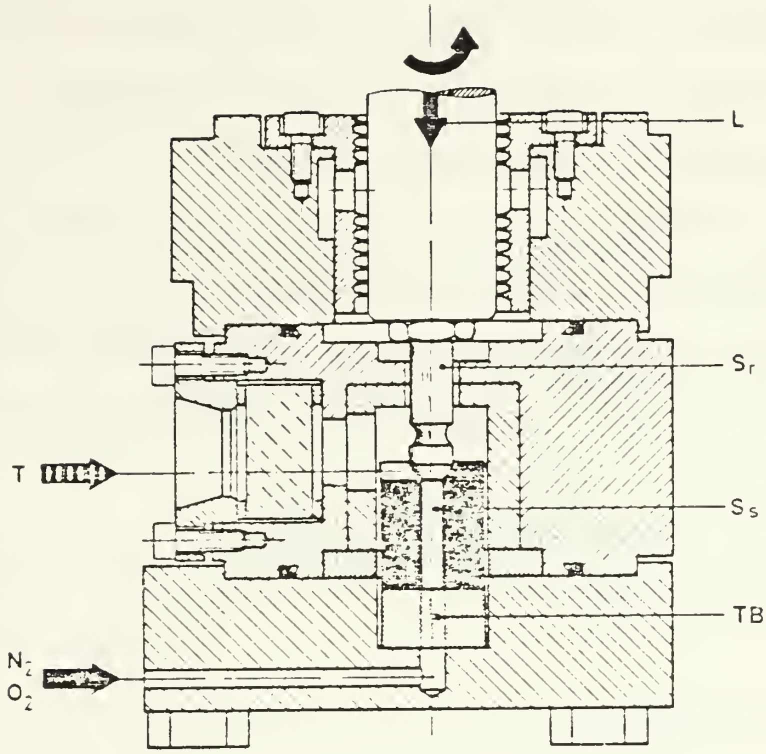


Figure 3.11. Schematic of Jenny and Wyssmann's Test Apparatus for Ignition Tests. L = Axial Load, S = Rotating Specimen, S_s = Stationary Specimen, T_B = Torque Strain Gage Balance, and T = Temperature Measurement with Pyrometer. Taken from [Ref. 14]

u = Average sliding velocity (m/s)

a = Thermal diffusivity

Δ = Laplace operator

T_e = Temperature of interface between S_r and S_s (Kelvin)

T_a = Temperature ambient (Kelvin)

α = Heat transfer coefficient

ε = Emissivity

σ = Stefan-Boltzmann constant

T_E = Temperature at equilibrium (Kelvin)

Equation 3.5 determines the oxidation energy by subtracting the frictional energy input in GOX from the total energy developed in the inert (N_2) gas configuration. The assumptions required to develop Equation 3.5 are broad, a one dimensional model is assumed using partly cylindrical and partly spherical coordinates, while the radiative and convective heat losses are assumed to be defined as Equations 3.6 and 3.7 with A, σ, and ε assumed as constants.

$$\dot{Q}_{ox}(T_E) = \dot{Q}_{dis}(T_E)\big|_{N_2} - \dot{Q}_f(T_E)\big|_{O_2} \qquad \text{(eqn 3.5)}$$

$$\dot{q}_{ra} = \sigma\ \varepsilon(T^4 - T_a{}^4) \qquad \text{(eqn 3.6)}$$

$$\dot{q}_c = \alpha\ (T - T_a) \qquad \text{(eqn 3.7)}$$

After a time interval of approximately 20 seconds the test results become quasi stationary (see Figure 3.12) at which point Jenny and Wyssmann assume a steady state condition inferring the functional dependence of μ (coefficient of friction). They assume values for A and E beforehand and fit the value of $\dot{Q}_{ox}(T_E)$ to the Arrenhius equation to obtain a curve of energy rate versus temperature of the interface.

Combining the results of all their testing Jenny and Wyssmann [Ref. 14] produce a graphical ranking of the materials tested (see Figure 3.13) which shows Monel K500 to be superior to 410 SS, Cast Iron and Tin Bronze.

As a result of fires associated with metal ignitions NASA began a program in the fall of 1981, which was designed

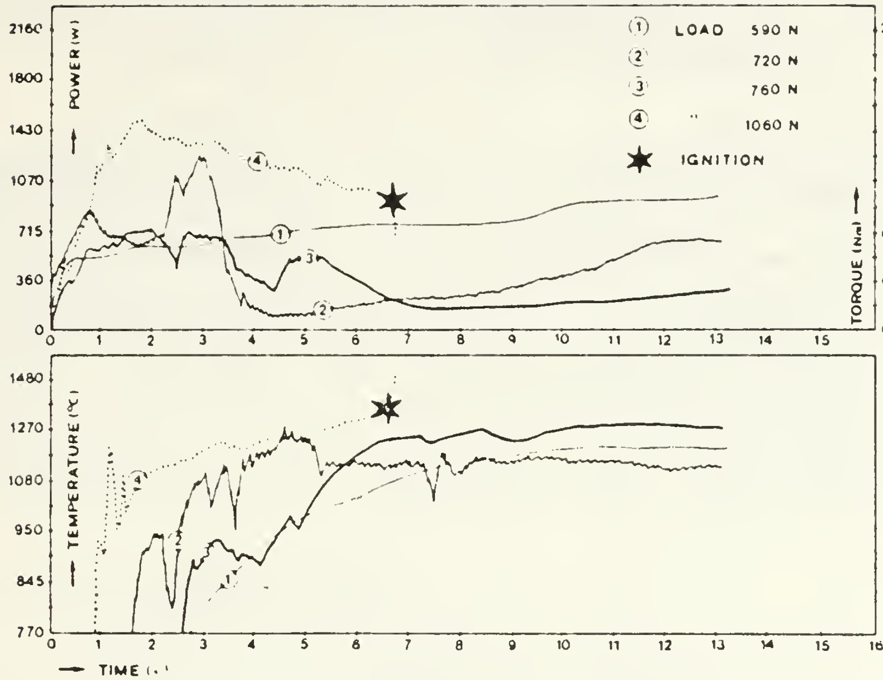


Figure 3.12. Temperature and Friction Power Records From Oxygen Tests (O_2) with GGG 40 (S_x) and X20Cr13 (S_r)
[Taken from Ref. 14]

to develop and test methods of ranking metals for service in GOX systems. A steering committee comprised of representatives from NASA WSTF, NASA Kennedy Space Center (KSC), Air Products and Chemicals Inc., The Jet Propulsion Laboratory, Rockwell-Downey, BOC Technical Center, Union Carbide Linde Division, NASA Johnson Space Center (JSC), and Aerojet Liquid Rocket Company met to determine what alloys should be ranked and by what test method the ranking should be accomplished. [Ref. 15].

Fifteen alloys were chosen for evaluation based on their current use in GOX systems, they were:

- 316 Stainless Steel
- 304 Stainless Steel
- Monel 400
- Aluminum 6061-T6
- Inconel 600
- Inconel718
- 17-4 PH Stainless Steel
- Brass 360
- Ti-6Al-4V
- Nickel 200
- Copper 102
- 1015 Carbon Steel
- Hastelloy X
- 440C Stainless Steel
- Invar 36

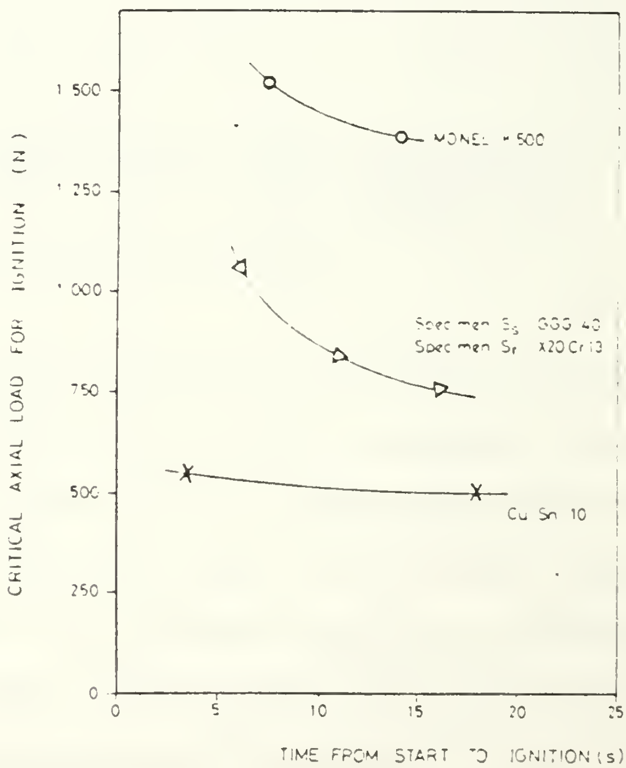


Figure 3.13. Ranking of Tested Materials with Respect to Ignition in Oxygen.
Taken from [Ref. 14]

The test methods are listed in Figure 3.14.

Criteria and Weighting Factors / Test Methods	Is the Test Method Capable of Ranking Metals? (4X)	Cost? (3X)	Is the Test Method Capable of Providing Analytical Data? (1X)	What is the Occurrence of the Ignition Source in Real Systems? (1X)	Is the Ignition Source a Known Cause of Oxygen Fires in Real Systems? (1X)
Adiabatic compression		THIS RATING WILL BE MADE AT WSTF			
Electrical arc/spark					
Extrusion					
Friction rubbing					
Furnace heating					
High velocity gas					
Induction heating					
Laser heating					
Mechanical impact					
Metal rupture					
Particle impact					
Promoted ignition					
Puncture					
Resistance heating					
Resonance cavity					
*					
*					

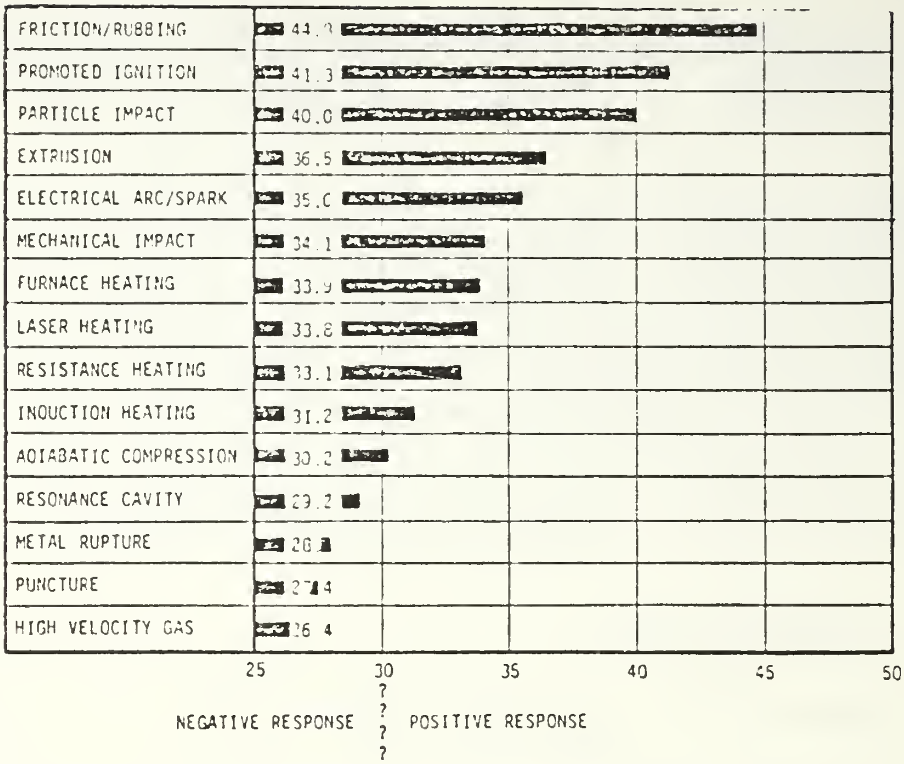
*Space allowed for adding identified test methods

Figure 3.14. WSTF Test Method Rating.
Taken from [Ref. 15]

which is a copy of the balloting form used to survey the steering group. The results of the survey are included as Table VII. The survey rated testing methods based on the expected occurrence of a mode of ignition in a real system, the actual occurrence of GOX fires due to the ignition mode proposed, and the capability of producing a test configuration with repeatable and controllable parameters. As seen in Table VII the first choice was a friction rubbing test method. Therefore, NASA WSTF constructed a test mechanism (see Figure 3.15) which as seen in its exploded view Figure 3.16 has the capability to measure and control several parameters simultaneously. The surface temperature of the test specimens

TABLE VII

Survey Results Taken from [Ref. 15]



Results of the test method selection survey. Does not include cost.

was measured by thermocouples and two-color pyrometers while the speed of rotation and the axial loading were varied independently.

The initial data obtained from the friction rubbing test method is presented in Table VIII, Monel 400 is superior to 316 SS in its resistance to ignition from frictional effects as demonstrated by the increased PV (Pressure X Velocity) product required to ignite Monel 400. Noted in [Ref. 15] was a result in the friction rubbing test where

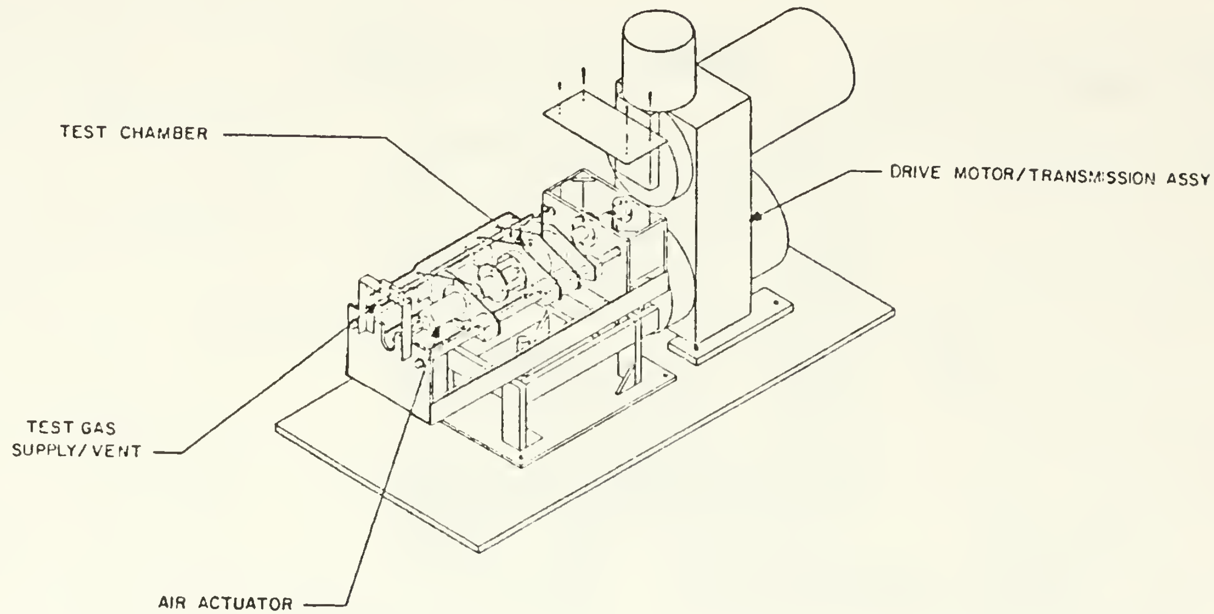


Figure 3.15. Schematic of Friction Rubbing Test Apparatus Taken from [Ref. 15].

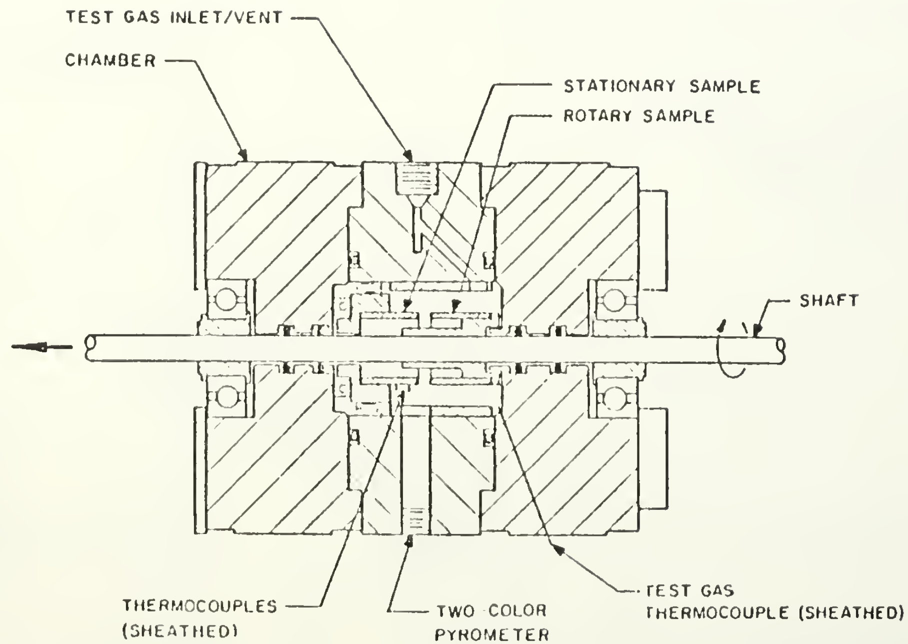


Figure 3.16. Chamber Exploded View Taken from [Ref. 15].

TABLE VIII

Friction Rubbing Results WSTF.
Taken from [Ref. 15]

4009 ft/m		2123 ft/min		1178 ft/min	
Material	PV Product (x 10^{-6})	Material	PV Product (x 10^{-6})	Material	PV Product (x 10^{-6})
		Nickel 200	*		
		Zi Cu	*		
Zi Cu	*	Brass 360	*		
Copper 102	*	Copper 102	*		
Nickel 200	6.6-8.8				
Inconel 600	5.7-8.3	Inconel 600	3.9-4.8		
Monel 400	4.2-4.6	Monel 400	3.0-3.6	Monel 400	3.1-3.3
Monel K-500	4.1-4.7	Inconel 718	2.1-3.4	304 SS	1.8-2.2
17-4 PH (HT)	3.0-3.4	304 SS	1.9-2.0	316 SS	1.7-1.9
Invar 36	2.8-2.9	17-4 PH (HT)	1.8-2.3	Inconel 718	1.6-1.7
Hastelloy X	2.6-3.2	17-4 PH (ANN)	1. -2.4	1015 C Steel	.9-1.8
Brass 360	2.1-3.6	316 SS	1.3-1.4		
17-4 PH (ANN)	1.8-3.1	1015 C Steel	1.2-1.5		
316 SS	1.7-2.1	Alum 6061-T6	.22		

*Failed Mechanically, Did Not Burn

1015 carbon steel 316 SS and Monel 400 increases in the amount of PV product required to ignite the individual test articles with an increase in the internal pressure of the reaction chamber for pressures above 3.4 MPa (500 psi). This result is contradictory to the relationship established by Kirchfeld [Ref. 17] were the reaction rate of metals increased with increasing pressure of GOX. This should lead to a decrease in the required PV product in friction rubbing tests with increases in the chamber pressure. A full explanation of this result can only come with further testing.

3. Foreign Materials/Softgood Ignition

Nihart and Smith [Ref. 9] as noted in the Ranking of Metals section conducted promoted ignition tests with the results as listed in Table II. Their ranking placed Monel superior to austenitic stainless steel as the amount of neoprene ignitor was doubled for Monel 400. This method of ranking metals simulates the ignition of a foreign substance within a GOX system which may then produce enough heat to ignite the metals comprising the system. This has been the suspected source of ignition in many actual GOX fires but often specific accidents involve litigation and are not easily cited. Civilian diving contractors have circulated safety messages which describe the improper installation of a valve that is not cleaned for GOX service into a diving system. The resulting fire could not be attributed to the use of the wrong construction material but rather to a human

error in a maintenance procedure. Therefore, promoted ignition should be considered a viable testing and ranking method.

Kirchfeld [Ref. 16] worked throughout the 1960's using promoted ignition of test articles of wire of varying diameters, with sponge iron or aluminum powder pills and nickelline ignitors. His initially studies were in a 1 ATM chamber but he progressed to a chamber capable of maintaining a 200 ATM (2940 psi) internal GOX pressure. Testing individual light and heavy metals such as aluminum and iron respectively, he ascribed reaction types based on the velocities of propagation/ reaction rates and observation of physical characteristics of the combustion. For iron Kirchfeld found what he termed a heterogenous reaction between the GOX and liquid oxide drops which formed on the surface of the reacting wire. The propagation velocity of iron was relatively slower than that for light metals such as aluminum, which combust in a homogeneous (vaporization) reaction. This relative reaction rate was consistent for both low 1 ATM pressures and higher 200 ATM pressures. Kirchfeld did find a transition from a heterogenous reaction to a homogenous reaction (combustion of evaporated gaseous iron in GOX) for 1mm diameter iron wire exposed to GOX pressures above 64 ATM. For pure metals Kirchfeld [Ref. 17] found the reaction rate of iron increased proportional to the square root of the GOX pressure and exhibited the transition just described. The transition was

assumed to be related to the presence of higher oxides, for example, Fe_3O_2 in iron combustion. The absence of higher oxides in the case of Nickel is postulated to be the reason that Kirchfeld was unable to combust Nickel wires in GOX atmospheres up to 200 ATM. This result demonstrates when combined with the fact that high alloy chrome nickel steels combust rapidly in GOX that simple addition of the heats of oxidation of the alloying agents will not predict the combustibility of a metallic alloy.

In more recent research conducted at Air Products and Chemicals, Slusser and Miller [Ref. 18] specifically tested Monel 400, AISI 304 S.S., carbon steel and gray cast iron in flowing GOX. Slusser and Miller considered the extent of combustion as being represented by the area consumed as a percentage of the area exposed. Based on this criterion Monel 400 and AISI 304 S.S. performed well (less than 4% of the area consumed) as compared to carbon steel. They reported "Type 304 stainless steel was also considerably superior to carbon steel and only slightly poorer than Monel 400". This difference between carbon steel and stainless steel (AISI 304) lead them to question Figure 3.17, which is a copy of a figure presented in the Compressed Gas Association pamphlet G-4.4, titled "Industrial Practises for Gaseous Oxygen Transmission and Distribution Piping Systems". Slusser and Miller question the all inclusive nature of the velocity versus pressure curve as it is presented in the CGA pamphlet

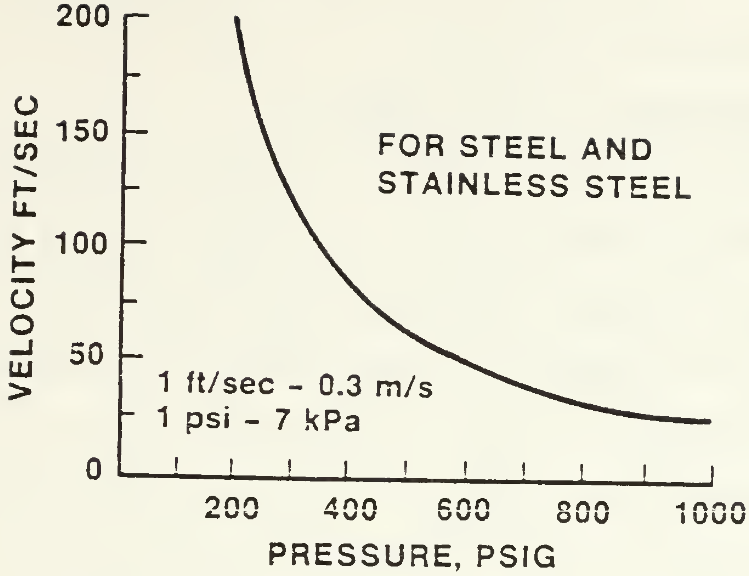


Figure 3.17. CGA Curve of Vel/Pressure Taken from [Ref. 18]

because it lumps both carbon steel and stainless steel; their own results contradict this curve's premise. They are presently continuing this research and may present their finds at the ASTM symposium in April of 1985.[7]

NASA is also currently conducting promoted ignition tests of the 15 materials listed earlier. The review of this testing noted a tendency for the test to become a propagation rate study when additional promoter is added to a material to cause ignition. This addition of material not only increases the energy input from the combustion of the added ignitor but

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[7]Source phone conversation between author and Joseph Slusser of Air Products and Chemicals Inc. on 9/28/84.

the area exposed to the heating prior to ignition/combustion of the metal is increased. The final results for this study are not presently published.

4. Resistance (Joule) Heating

Resistive heating of a specimen of pure metal or alloy has been used by Reynolds et. al. [Ref. 19] and Dean and Thompson [Ref. 8] and other investigators in both static and dynamic GOX environments. This method is particularly suited to the measurement of ignition temperatures of alloys at different pressures of GOX. It is most often used with an optical pyrometer as the method of measuring the temperature at which the specimen ignites. However, in the case were dynamic (flow of GOX) conditions can be maintained, the results are of greater interest. Research conducted by Dean and Thompson and included as Figure 1 is a good example of this technique. This method is less relevant and correspondingly unlikely as a real source of metal ignition, compared to friction rubbing, particle impact or promoted ignition test methods.

5. Resonance

The resonance-tube phenomenon originally described in research involving the production of high intensity sound waves has been proposed by Diehl [Ref. 20] Belles [Ref. 21] and Phillips [Ref. 22] as a possible ignition method in GOX fires. Research at NASA Lewis has demonstrated that the tee union, often used in gas piping systems, can in an appropriate

configuration (dead-ending one section of the tee) produce resonance. In laboratory simulation (see Figure 3.18) Phillips was able to measure temperatures in excess of 1000°C (1800°F) in the dead-end tee section when the inlet pressure of GOX was 7.6 MPa (1000 psi). After initially testing empty chambers at various stagnation pressures, Phillips conducted experiments using inert asbestos fibers released into the resonance tube. He later tested for ignition by resonance using aluminum fibers (1.5 mil x 1 mil) in cross sectional area by (0.5-0.7 inches) long. The apparatus as shown in Figure 3.18 included both stainless steel and quartz resonance

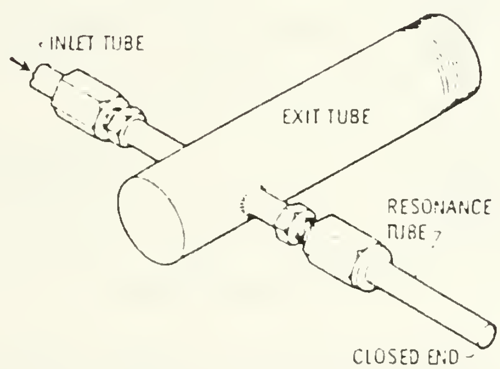

Figure 3.18. Phillips Resonance Tee Configuration. Taken from [Ref. 22]

tubes, with instrumentation composed of pressure transducers and thermocouples. His results as shown in Figure 3.19 include observations made by high speed photography and demonstrate the ignition of aluminum fibers in a resonance tube. Phillips considers the failure of a component in a high pressure GOX system with a concurrent rapid decompression of the system to be adequate to establish resonance within the piping system. His results demonstrate the short time frame required to produce ignition by the resonance phenomenon (5-10 s) with aluminum fibers present. He therefore concluded that ignition by resonance is possible in real systems [Ref. 22].

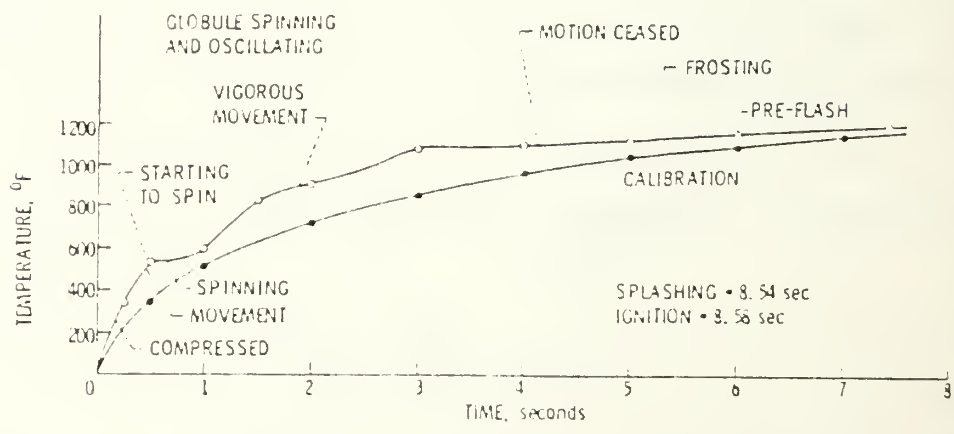

Figure 3.19. Ignition of 13 mg of Aluminum Fiber for an Inlet Stagnation Pressure of 1270 psia. Taken from [Ref. 22]

An important consideration that is noted by Phillips is the effect of the insulative rather than conductive characteristic of a quartz tube. All of the ignitions recorded were in quartz resonance tubes. Elevated temperatures were recorded in the AISI 304 resonance tubes and in one case the quartz tube ignited and in turn ignited the stainless steel section of the test apparatus, but no ignition of a tube composed of AISI 304 was recorded.

This method of ignition could be used for further testing of propagation rates using an interior promoter with a low flame temperature within the range of temperatures produced in a resonance tube.

6. Mechanical Impact

This test method consists of positioning a foil of a test material and impacting it with a known mass falling through a known distance which gives a reproducible energy of impact. An ignition is recorded based on the presence of a flash of light or the emission of a loud sound or evidence of burning in the holder or in the remains of the specimen. Batch testing using this method for nonmetals has become a principle selection criterion for GOX service and the method is also used to study and rank compatibility of metals with liquid oxygen (LOX). However, as a method for ranking it is not considered appropriate as it is difficult to ignite most metals with this method and attempts to increase the pressure of GOX in the holder have not been successful in providing

reproducible results. An extension of the impact method which places a contaminate material in the specimen cup was used by Ordin [Ref. 23] to compare AISI 304 stainless steel and 6061-T6 aluminum. The AISI 304 was nonreactive at the maximum range of pressure 34.6 MPa (5000 psi), temperature 811 K ($1000^{o}F$) and impact energy levels 252 J/cm^2 (1200 $ft\text{-}lb/in^2$) in any contaminate including motor oil, copper powder, tool makers dye and cutting oil. The aluminum was reactive without contaminates and increased in its reaction with contamination by the oil products.

III. THE THEORY OF BULK METAL IGNITION

The early work in postulating a theory of bulk metal ignition is reviewed in [Ref. 27]

The difficulty in quantifying metals ignition parameters, such as T_{ign} (ignition temperature) and T_{crit} (critical temperature) lie in the extensive number of factors which can affect the ignition process. Bransford and Clark [Ref. 26] have produced a table included here as Figure 4.1 which lists three major categories and numerous dependent and independent variables in metal ignition processes.

Equation 4.1 is driven to the right by free energy considerations and is exothermic for all metals at ambient temperatures, with the single exception of gold. This point of commonality is the only one in ignition of metals, the various methods of ignition can be grouped according to proposed reaction mechanisms but the groupings are the subject of some controversy. Several factors combine to confuse the ignition and subsequent combustion of metals, major among these are a dependence of ignition upon the preignition surface conditions and the formation of solid phase products on the surface. [Ref. 28]

$$aMe + b/2O_2 \text{ -- } Me_aO_b \qquad \text{(eqn 4.1)}$$

The oxidation of a metal with its subsequent production of heat is labelled by Glassman et. al. [Ref. 28]in Figure 4.2

Material Properties*	Environmental	Configuration
atomic weight (m) molecular weight (mo) thermal conductivity (m+mo) thermal diffusivity (m+mo) heat capacity (m+mo) heats of solid phase transitions (m+mo) heat of fusion (m+mo) heat of vaporization (m+mo) heat of formation (m+mo) melting point (m+mo) boiling point (m+mo) ignition temperature (m) vapor pressure (m+mo) viscosity (m+mo) surface tension (m+mo) solubility of oxygen in metal (m) diffusivity of oxygen (m+mo) diffusivity of metal (m+mo) emissivity (m+mo) composition of metal (m) chemical reaction rates (m+mo) equilibrium constants (mo) solubility of oxygen in reaction products solubility of metal in reaction products density (m+mo) thermal expansion (m+mo) convective heat transfer coefficients	temperature pressure oxygen concentration presence of diluent nature of diluent gas velocity Reynolds number	history of metal state of surface oxide film thickness specific surface area (cm^2/g) total mass of metal presence of other metals (eutectic formation or thermite reaction possible) presence of contaminants centrifugal forces angle of attack heat and mass transfer coefficients

*m = metal
mo = metal oxide

Figure 4.1. Factors Effecting Metals Ignition. Taken from [Ref. 26]

(curve a) as $\dot{q}_{chem}$. In this generalized S-shaped curve the output of heat from oxidation of a metal is seen to vary in its functional relationship with the surface temperature of the metal T_s.

The possible oxidation rates can include a linear, parabolic or logrithmic section or a combination of these or other modes. Curb b of Figure 4.2 represents the rate of heat loss $\dot{q}_{loss}$ of a bulk metal as a function of the surface temperature of the metal T_s, again the curve is generalized and may include losses due to conduction, radiation and convection of a combination of these loss mechanisms.

Combining the $\dot{q}_{chem}$ and $\dot{q}_{loss}$ curves (see Figure 4.2 curve c) a generalized pattern of $\dot{T}_{surface}$ can be developed. Figure 4.3 again taken from Glassman et. al. [Ref. 28] demonstrates a further point of confusion in the literature which is centered on the definition of T_{ign} and T_{crit}. Glassman defines T_{crit} as the condition where at specific $T_{surface}$ the $\dot{q}_{chem}$ and $\dot{q}_{loss}$ terms are equal while T_{ign} is defined by Equation 4.2.

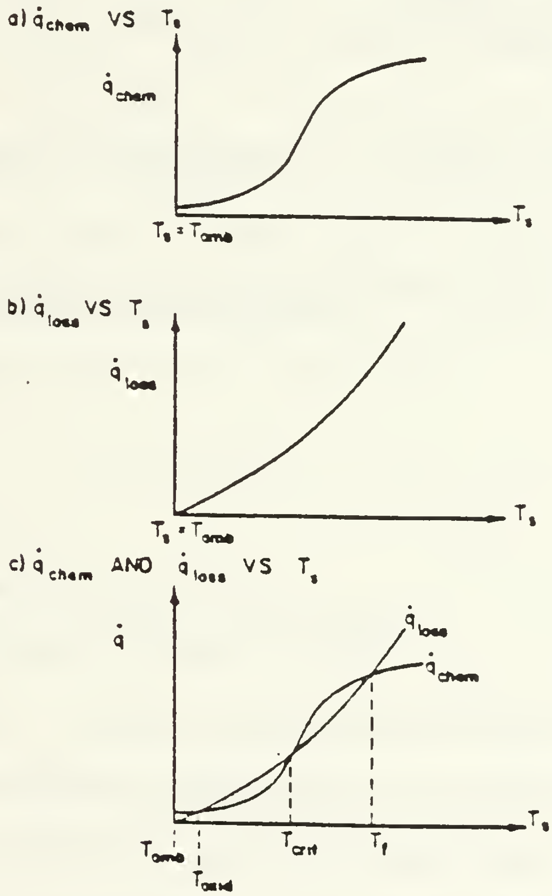

Figure 4.2. Curve of Ignition Mechanisms by Glassman. Taken from [Ref. 28]

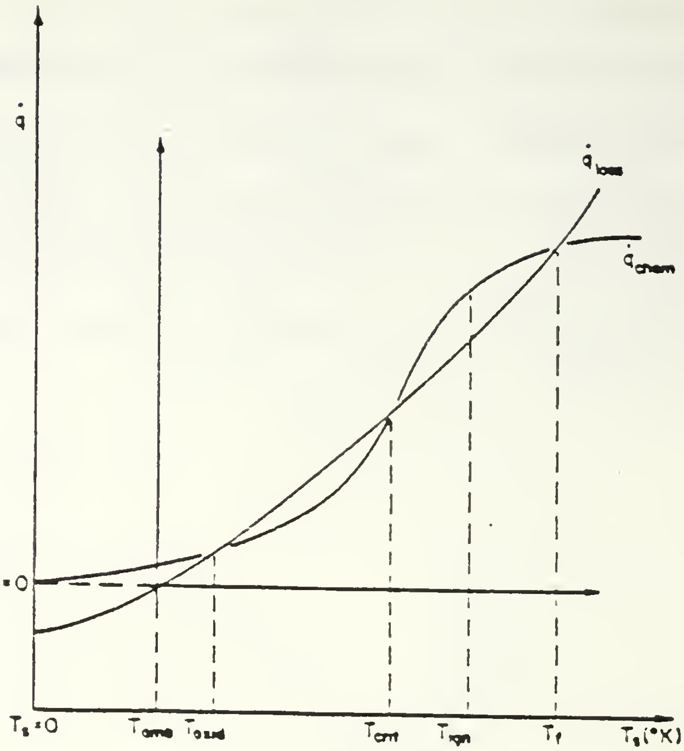

Figure 4.3. Summary Plot of $\dot{q}$ versus T_s. Taken from [Ref. 28]

$$\partial \dot{q}_{chem}/\partial T_s \Big|_{T_s} = T_{ign} = \partial \dot{q}_{loss}/\partial T_s \Big|_{T_s}$$

This distinction in T_{crit} and T_{ign} is often not made by researchers in this field which confuses comparison of analytical treatments and experimental results.

The graph of Figure 4.3 suggests a smooth transition from different oxidation rates as well as a smooth curve of heat loss, both assumptions require modification for each individual metal. Grouping of metals exhibiting similar discontinuities in their $\dot{q}_{chem}$ terms is often done but it assumes that a

specific reaction such as melting of the oxide layer, or boiling of the metals surface is responsible for the breaks in $\dot{q}_{chem}$. Another added complication of Figure 4.3 is how external heat additions are treated, the various ignition methods discussed in the Literature Review chapter are examples of heat additions all of which differ in their time dependency and in the surface areas they effect.

A recent attempt at analytically modelling bulk ignition which correlates experimental results from several test methods employed at NASA White Sands was proposed by Yuen in [Ref. 13]. The $\dot{q}_{chem}$ input of energy from the metal oxidation is assumed to result from a combination of a linear (see Equation 4.3) and a parabolic (see Equation 4.4) equation. The combined resultant is Equation 4.5 which expresses the total mass of metal reacted per unit surface area. This assumes that the value of E_l equal the

$$dM/dt = K_l \qquad \text{(eqn 4.3)}$$

$$dM^2/dt = K_p \qquad \text{(eqn 4.4)}$$

$$dM^2/dt = A_l/1+2M(A_l/A_p)\exp(-E/RT) \qquad \text{(eqn 4.5)}$$

value of E_p which in turn equals E, and defines reaction constants A_l for the linear and A_p for the parabolic equations. Using the combined metal oxidation equation a general heat balance can be modelled as Equation 4.6 with the parameters defined as:

ρ = density

V/S = the ratio of the effective volume to reacting surface area

C = the specific heat of the metal

dT/dt = time rate of change of the temperature

Q = the heat generated/gram of metal reacted

$h(T-T_\infty)$ = heat loss by convection

$\varepsilon\sigma(T^4-T_\infty^4)$ = heat loss by radiation

$H(t)$ = heat addition by the test method

$$\rho VCdT/Sdt = Q(A_1 \exp(-E/RT))/1+2MA_{1/A_p} - h(T-T_\infty) - \varepsilon\sigma(T^4-T_\infty^4) - \frac{1}{R_i}(T-T_i) + H(t)$$

(eqn 4.6)

This treatment has the same difficulty that most of the theoretical explanations suffer from, that is, its inability to incorporate the changing surface area, as is noted in Yuen's discussion; removal of the metal surface and the oxide layer is not well explained by this model.

IV. EXPERIMENTAL PROCEDURE

A. TEST OBJECTIVES

From the results reported by Wegener [Ref. 3] propagation of a flame against the flowing stream of GOX was not observed once a breach in the steel pipeline occurred due to heating by entrained particle contaminates. However, testing of a model for flame propagation in steel cylinders has been attempted by Sato et. al. [Ref. 24]. Utilizing a chamber with a preset GOX pressure and high speed photography, Sato's analysis defined the controlling parameters in the rate of fire spread as the diameter of the test article, the GOX pressure and the orientation of the test article. The possible spread of a fire in diving equipment or in the GOX life support system assuming an ignition source is present, raises the question of the flame propagation characteristics of Monel and austenitic stainless steel in a flowing system. The most relevant testing of propgation of flame in a flowing GOX environment is the research of Ivanov and Ul'Yanova [Ref. 25]. Their methods provided data on the results of ignition of the GOX flow within a closed pipe with a preset internal pressure and flow rate. Additional testing by Ivanov and Ul'Yanova measured propagation rates in pipe opened to the atmosphere with a set inlet pressure. Their study focused on three materials, aluminum, stainless steel and carbon steel. Within

the translation a correlation of flow rates of GOX to the combustion of stainless steel is developed (see page 6 of [Ref. 25]). This is a mistranslation, the specimens which show a correlation between flow rate and combustion were listed in the results as carbon steel.

B. DIVING EQUIPMENT SIMULATED

To test the flame propagation characteristics of Monel 400 and austenitic stainless steel an operational diving set the USN Mk 15 Underwater Breathing Apparatus (UBA) was chosen as the equipment to simulate (see Figure 5.1 for an overview of the equipment).

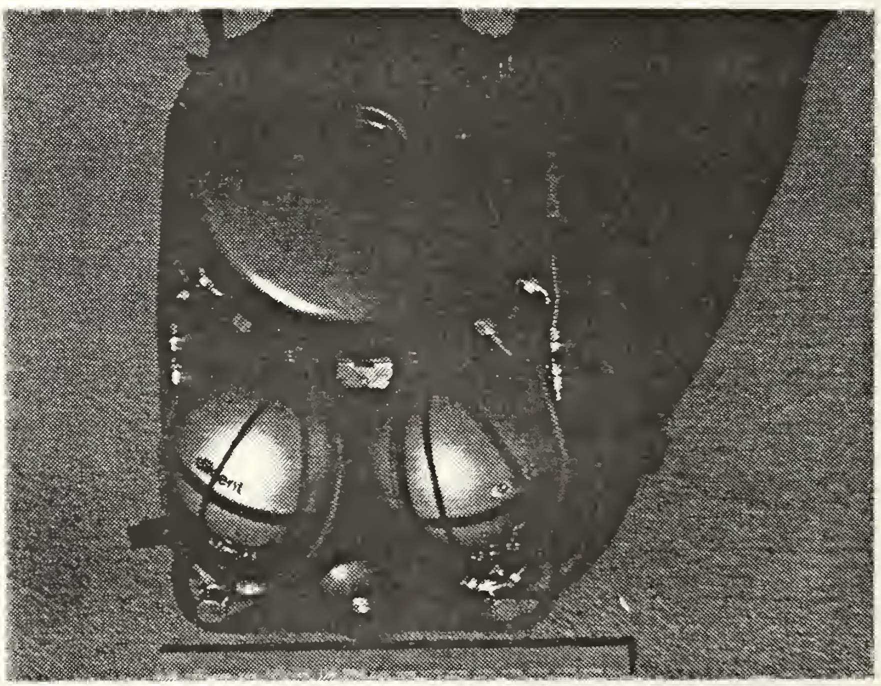

Figure 5.1. The USN Nk 15 UBA Full View Without Back Cover.

Flame propagation in the GOX assembly on the Mk 15 would require the fire to spread upstream in the GOX tubing, which is shown in the close-up of the oxygen assembly Figure 5.2. The Mk 15 which is based on a commercial diving set utilizes AISI 316 stainless steel 3.2x0.9 mm (1/8x.035in) I.D. tubing. The pressure regulator on the oxygen supply bottle is set to

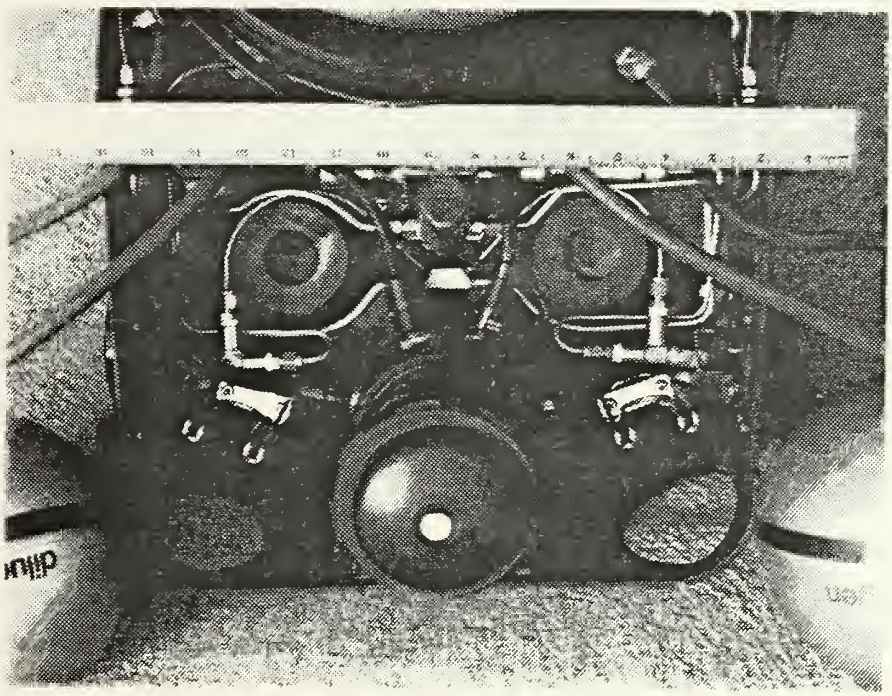

Figure 5.2. Close Up View of the USN Mk 15 UBA Oxygen Assembly.

maintain 0.8 MPa (110 psig) above ambient pressure in the oxygen assembly. The MK 16 UBA is similar in concept to the Mk 15 and utilizes the same type of tubing, but its oxygen regulator is set to maintain 2.0 MPa (295 psig). The testing of Monel 400 and AISI 316 was conducted at inlet pressures of both 0.8 MPa and 2.0 MPa respectively to simulate the breaching

of the oxygen assembly of either a Mk 15 or Mk 16 UBA and determine the extent to which a flame could propagate upstream against a GOX flow in these metals. In view of unpublished results obtained by NASA White Sands Test Facility an additional sample of AMS 5050, a carbon steel 3.2x0.9 mm I.D. tubing was included in the test matrix. An initial matrix was modified once the inability to ignite AISI 316 and Monel 400 was found. The modification consisted of attempting to find an inlet pressure at which flame propagation in AISI 316 and Monel 400 could be observed, this proved to be impossible. Another modification was devised to determine at what pressure the carbon steel tube flame propagation could be quenched by the GOX flow. A ramping of the test article inlet pressure was programmed into the test sequence.

V. EXPERIMENTAL APPARATUS

A. TEST SYSTEM

The experiment was conducted at the NASA White Sands Testing Facility in New Mexico, utilizing the certified GOX testing apparatus which can be seen in schematic form in Figure 6.1. The system delivers GOX at a controlled inlet pressure up to 41.3 MPa (6000 psi) and gas temperature up to 300°C (700°F). The GOX High Flow test system was modified using low pressure transducers as described in Appendix B. This modification allowed regulation of the test article inlet pressure to within 5 psig during each constant pressure run and also allowed ramping of the inlet pressure when it was required. Control of the GOX flow was maintained by the microprocessor and control network which through feedback from the pressure transducers at the inlet and outlet of the pressure control valve and the inlet transducer at the entrance to the test article opened or closed the pressure control valve as required to maintain a constant inlet pressure.

1. Data Acquisition

A digital data acquisition system both controlled the time sequencing of events for each test and recorded realtime data. The control room panel housed the microprocessor, strip chart recorder, monitors, floppy disc drives and associated circuitry which allowed totally remote control

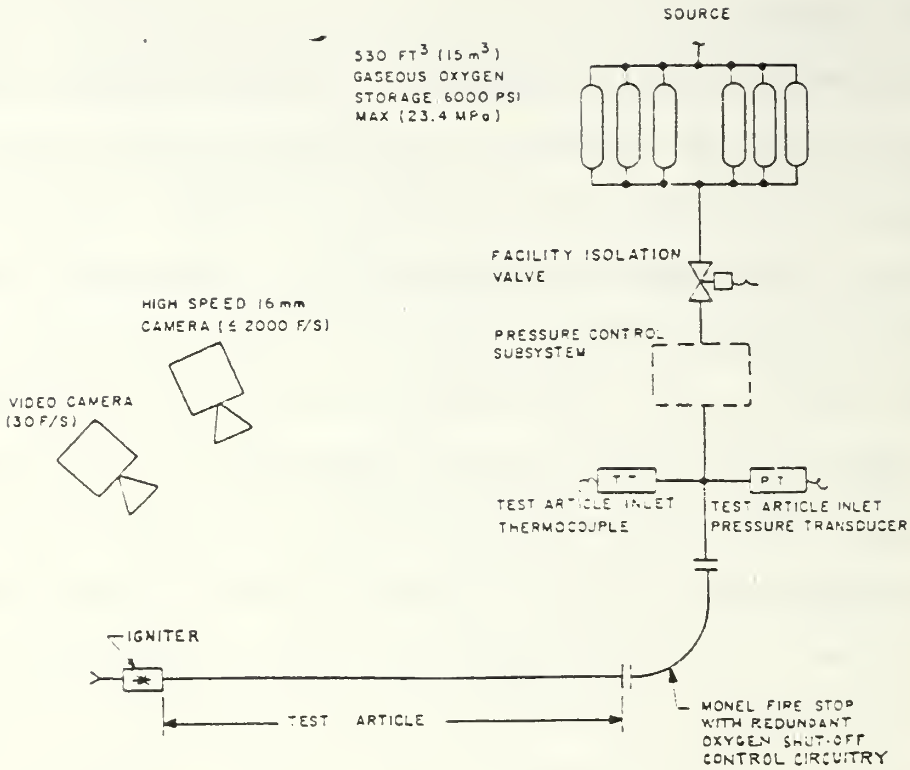

Figure 6.1. Test System Schematic.

of each test run. A typical test event is shown in Figure 6.2, note the multiple disc drives allowing flexibility in data acquisition. Also shown in this photograph is the system of position indicators and status lights which allow operator analysis and manual over-ride of the test sequence.

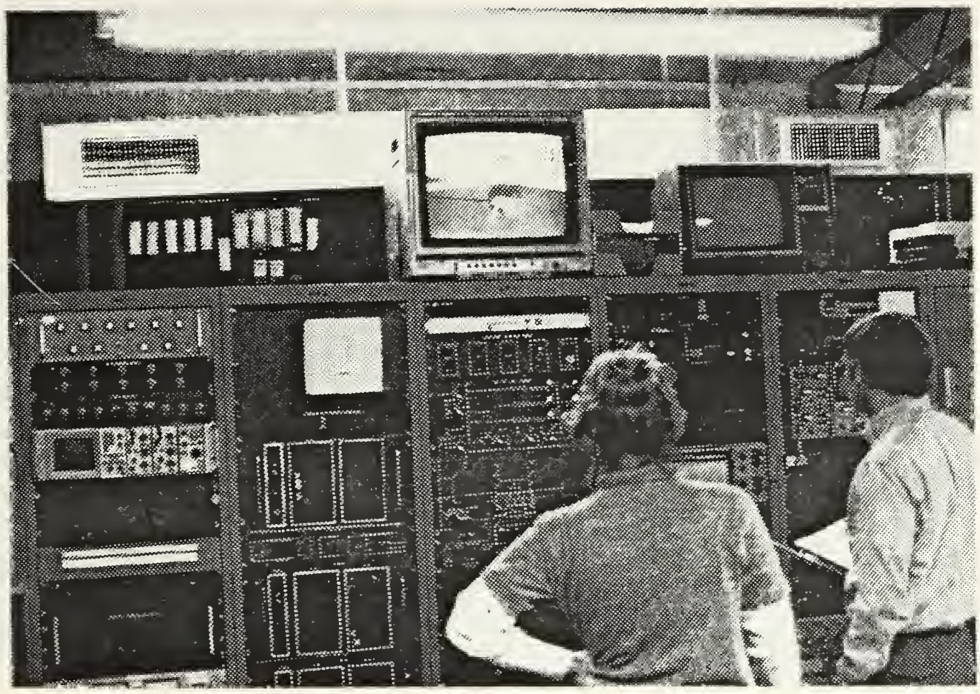

Figure 6.2. Control Room Panel During Test 243.06.

2. Test Sequence

Figure 6.3 shows the relationship of the spin physics high speed video camera to the test article, while Figure 6.4 shows the relative position of the ignitor a Victor oxyacetelene torch just prior to the start of a test sequence. A typical sequence for the Monel and AISI 316 constant pressure test would proceed with the establishment of the preset inlet pressure of GOX to the test article. Normal speed video was utilized for both Monel 400 and AISI 316 testing once the inability to propagate a flame was established. Video coverage and ignitor extension, which placed the tip of the test article

Figure 6.3. Overview of Test Site Showing Relationship of the High Speed Video to the Test Article.

at the apex of the inner cone of the oxyacetelene flame, were synchronized by the microprocessor which additionally initiated data collection from the channels containing the readout of the pressure transducers (PT-19, PT-26 and PT-100A), the test article inlet thermocouple and the position of the PCV. The ignitor was extended and programmed to remain in position for 15 seconds unless ignition occurred prior to the end of the 15 seconds in which case manual over-ride was employed. The torch was quenched by securing the flow of oxygen to it though the barrel remained extended for the full 15 seconds. This capability was used often in the test involving AMS 5050

Figure 6.4. Close Up of Test 243.14 Carbon steel T.A. in Vertical Orientation.

carbon steel tubing for ignition occurred rapidly for all test of carbon steel at initial inlet pressures below 40 psig. Once propagation against the flow was established in the AMS 5050 tubing sections the high speed video was utilized to record the event. This video was then edited by the addition of cursor marks and the realtime record which would allow accurate propagation rate measurements. The flexibility of the carbon steel tubing allowed testing of the flame propagation rates in three different orientations; horizontal, vertical downward, and vertical upward. From the initial intention of defining the flame propagation

characteristics of Monel and stainless steel, the majority of the test articles were either Monel or stainless steel which meant that only a limited number of tests were conducted using AMS 5050 carbon steel.

Both the Monel 400 and AISI 316 test article were cleaned for oxygen service according to the NAVSEA Tech Manual specification included as Appendix C. Additionally all the test articles including the AMS 5050 were flushed with freon prior to installation in the test apparatus.

VI. RESULTS

The results of the experiment are presented in Table IX; the computer printout of the data, as recorded in each test, is enclosed as Appendix A. Data recorded includes the inlet pressure of the GOX for each test, along with the propagation speed (if propagation occurred) and the volume flow rates as calculated in Appendix E.

The volume flow rate was calculated by recording the time required for a given pressure drop to occur in a known floodable volume. Correcting this flow rate to standard conditions and in the case of the 110 and 295 psig runs correcting for the difference in molecular weights between nitrogen and oxygen yielded the flow rates in standard cubic feet per minute or standard litres per minute. The propagation rates were calculated from the high speed video record. The horizontal and vertical downward orientations combined gave an average propagation rate of 1.85 mm/s (.07 in/s) as compared to the vertical upward orientations rate of 2.35 mm/s (.09 in/s). It appears there is a difference in the flame spread rate based on the orientation for AMS 5050 carbon steel tubing, also the propagation can be extinguished by increasing the pressure.

TABLE IX

Experimental Results

Material	Test No.	Pt-100a (Psi)	Ignition occurred	Propagation (in/s)	Flow rate (SCFM/SLPM)
Monel	243.03	110	No	NA	2.13/60.2
Monel	243.09	295	No	NA	5.43/153.9
AISI 316	243.06	110	No	NA	2.13/60.2
AISI 316	243.08	295	No	NA	5.43/153.9
AISI 316	243.07	Ramp 20-80	No	NA	0.5/13.2
AMS 5050	243.04	110	Yes	Extinguished	2.13/60.2
AMS 5050	243.05	20	Yes	No High Speed Video	0.5/13.2
AMS 5050 Horizontal	243.10	Ramp 20-45 Extinguish	Yes	.075	0.5/13.2
AMS 5050 Horizontal	243.11	Ramp 30-45 Extinguish	Yes	.068	0.5/13.2
AMS 5050 Vertical Down	243.12	Ramp 20-45 Extinguish	Yes	High Speed Video Lock up	0.5/13.2
AMS 5050 Vertical Down	243.13	Ramp 20-45 Extinguish	Yes	.075	0.5/13.2
AMS 5050 Vertical Up	243.14	Ramp 20-60 Extinguish	Yes	.086	1.3/35
AMS 5050 Vertical Up	243.15	Ramp 20-60 Extinguish	Yes	.99	1.3/35

VII. CONCLUSIONS

The major conclusions that may be drawn from the literature review and experimental results are as follows:

1. The literature which attempts to rank metals compatibility for GOX service is confused due to two factors -
   a. Individual research efforts consider limited (usually a single) ignition source based on a specific design configuration.
   b. Proprietary information on testing of materials for GOX service is in some cases restricted from open publication.
2. There is no significant difference in flame propagation rates between Monel 400 and AISI 316 stainless steel when they are subjected to conditions which simulate the breach of a GOX system with internal pressures from .14-2.0 MPa (20-295 psig).
3. There appears to be a significant difference in flame propagation rates for AMS 5050 carbon steel tubing 3.2 x .89mm (1/8 x .035 inches) between the upward vertical and horizontal orientation. The upward vertical orientation yields the faster propagation rate 2.3 mm/s (.09 in/s).

4. Modelling of the ignition and combustion of metals is difficult due to the heterogenous nature of the combustion and the large number of variables which affect the process.

RECOMMENDATIONS

1. The diving branch of NAVSEA should seek representation on the ASTM G-4 committee on Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres.
2. NAVSEA should maintain a liaison with NASA White Sands Test Facility to remain abreast of their recent efforts to develop and evaluate testing methods for ranking of metals for GOX service.
3. The current trend to group carbon steel and stainless steel in developing design curves for GOX equipment construction is not appropriate. From the difference in propagation rates in flowing systems it is evident that these metals are not equal in their compatibility with GOX.

APPENDIX A

Computer Printout of Experimental Results

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 244.01
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION FLOW TEST

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/95	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 244.01

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	69	330	13	13	13	0	0	30
-8.0	70	330	12	13	12	0	0	30
-7.0	69	321	13	13	12	0	0	30
-6.0	69	321	13	13	13	0	0	30
-5.0	69	321	13	13	13	0	0	30
-4.0	70	330	12	13	12	0	0	30
-3.0	70	321	12	13	12	0	0	30
-2.0	69	321	13	13	13	0	0	30
-1.0	69	321	13	13	12	0	0	30
0.0	69	321	12	13	13	0	0	30
1.0	70	321	331	25	59	0	0	40
2.0	76	321	284	148	205	0	0	51
3.0	82	313	323	270	277	0	0	45
4.0	83	313	334	298	300	0	0	38
5.0	82	321	334	301	302	0	0	33
6.0	82	313	334	300	302	0	0	33
7.0	79	321	334	300	301	0	0	33
8.0	78	321	333	300	301	0	0	33
9.0	77	313	333	300	301	0	0	33
10.0	76	313	333	300	301	0	0	33
11.0	74	313	333	300	301	0	0	33
12.0	73	313	333	300	300	0	0	32
13.0	73	313	333	299	300	0	0	32
14.0	72	313	333	299	299	0	0	32
15.0	70	321	333	298	299	0	0	32
16.0	70	313	333	298	298	0	0	32
17.0	69	313	333	297	298	0	0	32
18.0	69	321	333	297	297	0	0	32
19.0	68	313	333	297	298	0	0	32
20.0	68	313	333	297	297	0	0	32
21.0	68	321	333	297	297	0	0	32
22.0	68	321	333	297	298	0	0	32
23.0	68	313	333	298	298	0	0	32
24.0	68	313	333	298	299	0	0	32
25.0	67	321	333	299	299	0	0	32
26.0	66	321	333	299	300	0	0	32
27.0	67	313	333	299	300	0	0	32
28.0	67	313	333	300	300	0	0	32
29.0	67	313	333	300	301	0	0	32
30.0	67	313	333	300	301	0	0	32
31.0	67	313	332	301	301	0	0	32
32.0	66	313	332	301	301	0	0	32
33.0	67	321	332	301	301	0	0	32
34.0	67	321	332	300	301	0	0	32
35.0	66	321	332	300	300	0	0	32
36.0	67	313	332	299	299	0	0	32
37.0	66	313	332	298	299	0	0	32
38.0	66	313	332	298	298	0	0	32
39.0	66	313	332	297	298	0	0	32
40.0	57	305	332	297	300	0	0	32
41.0	66	321	332	296	297	0	0	32
42.0	66	313	332	295	296	0	0	32
43.0	66	313	332	295	296	0	0	32
44.0	66	313	332	295	296	0	0	32
45.0	66	321	332	296	297	0	0	33
46.0	66	313	332	297	298	0	0	33
47.0	66	321	332	298	299	0	0	33
48.0	66	313	332	300	300	0	0	33
49.0	67	313	332	300	301	0	0	33
50.0	66	321	332	301	302	0	0	33
51.0	66	313	332	302	303	0	0	33
52.0	67	313	332	303	303	0	0	33
53.0	67	313	332	303	304	0	0	33
54.0	67	321	332	303	303	0	0	32
55.0	67	313	332	302	303	0	0	32
56.0	66	313	332	301	301	0	0	32
57.0	66	313	332	300	301	0	0	32
58.0	66	313	332	299	300	0	0	32
59.0	66	313	332	299	299	0	0	32
60.0	66	313	332	298	298	0	0	32
61.0	66	321	331	297	298	0	0	32
62.0	66	321	331	296	297	0	0	32

TEST NUMBER 244.01

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	65	321	331	296	296	0	0	32
64.0	66	313	331	295	296	0	0	32
65.0	66	313	331	295	296	0	0	32
66.0	65	321	331	296	296	0	0	32
67.0	65	313	331	296	297	0	0	33
68.0	66	313	331	297	298	0	0	33
69.0	66	321	331	298	299	0	0	33
70.0	66	313	331	299	300	0	0	33
71.0	65	313	331	300	301	0	0	33
72.0	67	321	331	301	302	0	0	33
73.0	66	321	331	302	302	0	0	33
74.0	66	313	331	302	303	0	0	33
75.0	66	313	331	302	303	0	0	32
76.0	66	313	331	302	303	0	0	32
77.0	66	313	331	301	302	0	0	32
78.0	66	313	331	300	301	0	0	32
79.0	67	313	331	300	300	0	0	32
80.0	66	313	331	299	300	0	0	32
81.0	66	313	331	298	299	0	0	32
82.0	66	313	331	298	298	0	0	32
83.0	66	313	331	297	297	0	0	32
84.0	66	313	331	296	297	0	0	32
85.0	65	313	331	296	296	0	0	32
86.0	66	313	331	295	295	0	0	25
87.0	66	313	331	292	292	0	0	9
88.0	66	313	331	290	290	0	0	0
89.0	66	313	331	287	288	0	0	0
90.0	65	313	331	285	285	0	0	0
91.0	65	313	331	283	283	0	0	0
92.0	65	313	331	281	281	0	0	0
93.0	65	313	331	279	279	0	0	0
94.0	65	313	331	277	277	0	0	0
95.0	65	313	331	275	275	0	0	0
96.0	64	313	331	273	273	0	0	0
97.0	65	313	331	271	271	0	0	0
98.0	64	313	331	269	269	0	0	0
99.0	64	313	331	267	268	0	0	0
100.0	65	313	331	265	266	0	0	0
101.0	65	313	331	263	264	0	0	0
102.0	64	313	331	262	262	0	0	0
103.0	65	313	331	260	260	0	0	0
104.0	65	313	331	258	258	0	0	0
105.0	65	313	331	256	257	0	0	0
106.0	64	313	331	255	255	0	0	0
107.0	65	313	331	253	253	0	0	0
108.0	64	313	331	251	252	0	0	0
109.0	64	313	331	250	250	0	0	0
110.0	65	321	331	248	249	0	0	0
111.0	64	313	331	247	247	0	0	0
112.0	65	313	331	245	245	0	0	0
113.0	65	313	331	244	244	0	0	0
114.0	65	313	331	242	242	0	0	0
115.0	65	313	331	240	241	0	0	0
116.0	65	313	331	239	239	0	0	0
117.0	64	313	331	238	238	0	0	0
118.0	65	313	331	236	236	0	0	0
119.0	65	313	331	235	235	0	0	0
120.0	64	321	331	233	234	0	0	0
121.0	64	313	331	232	232	0	0	0
122.0	65	313	331	231	231	0	0	0
123.0	65	313	331	229	230	0	0	0
124.0	65	313	331	228	228	0	0	0
125.0	65	313	331	226	227	0	0	0
126.0	64	313	331	225	225	0	0	0
127.0	65	313	331	224	224	0	0	0
128.0	64	313	331	223	223	0	0	0
129.0	65	313	331	221	222	0	0	0
130.0	65	313	331	220	220	0	0	0
131.0	65	313	331	219	219	0	0	0
132.0	66	313	331	218	218	0	0	0
133.0	65	313	331	217	217	0	0	0
134.0	65	313	331	216	216	0	0	0

TEST NUMBER 244.01

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
135.0	65	313	331	214	214	0	0	0
136.0	65	313	331	213	213	0	0	0
137.0	65	313	331	212	212	0	0	0
138.0	65	313	331	211	211	0	0	0
139.0	65	313	331	210	210	0	0	0
140.0	65	313	331	209	209	0	0	0
141.0	65	313	331	208	208	0	0	0
142.0	65	313	331	206	207	0	0	0
143.0	65	313	331	205	206	0	0	0
144.0	65	313	331	204	204	0	0	0
145.0	65	313	331	203	204	0	0	0
146.0	66	313	331	202	202	0	0	0
147.0	65	313	331	201	202	0	0	0
148.0	65	313	331	200	201	0	0	0
149.0	65	313	331	199	199	0	0	0
150.0	65	313	331	198	199	0	0	0
151.0	65	313	331	197	198	0	0	0
152.0	66	313	318	196	197	0	0	0
153.0	65	313	295	195	196	0	0	0
154.0	65	313	277	194	194	0	0	0
155.0	65	313	262	193	193	0	0	0
156.0	64	313	249	192	192	0	0	0
157.0	65	313	238	190	190	0	0	0
158.0	65	313	229	189	189	0	0	0
159.0	65	313	220	188	188	0	0	0
160.0	65	313	213	186	187	0	0	0
161.0	66	313	206	185	185	0	0	0
162.0	65	313	201	184	183	0	0	0
163.0	65	321	196	182	182	0	0	0

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.02
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION FLOW TEST

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.02

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.3 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	70	313	12	12	12	0	0	30
-8.0	70	313	12	12	12	0	0	30
-7.0	70	313	12	12	13	0	0	30
-6.0	·70	313	12	12	13	0	0	30
-5.0	70	313	12	12	12	0	0	30
-4.0	70	313	12	12	12	0	0	30
-3.0	70	313	12	12	13	0	0	30
-2.0	69	313	12	12	13	0	0	30
-1.0	70	313	12	12	12	0	0	30
0.0	70	313	12	12	12	0	0	30
1.0	70	313	329	22	45	0	0	39
2.0	74	313	326	74	90	0	0	39
3.0	77	313	330	106	109	0	0	36
4.0	77	313	331	113	113	0	0	31
5.0	78	313	330	114	114	0	0	30
6.0	77	321	330	114	114	0	0	29
7.0	76	313	330	115	115	0	0	29
8.0	75	313	330	115	115	0	0	28
9.0	75	313	330	115	115	0	0	28
10.0	74	313	330	115	115	0	0	27
11.0	74	313	330	115	115	0	0	27
12.0	73	313	330	114	114	0	0	27
13.0	73	313	330	114	114	0	0	26
14.0	73	313	330	114	114	0	0	26
15.0	72	313	330	114	114	0	0	25
16.0	72	313	330	113	113	0	0	25
17.0	70	313	330	113	113	0	0	25
18.0	72	313	330	113	113	0	0	24
19.0	70	313	330	113	113	0	0	24
20.0	70	313	330	113	113	0	0	23
21.0	70	313	330	113	112	0	0	23
22.0	70	313	330	113	112	0	0	22
23.0	69	313	330	112	112	0	0	22
24.0	69	313	330	112	112	0	0	22
25.0	69	313	330	112	112	0	0	22
26.0	69	313	330	112	112	0	0	21
27.0	69	313	330	112	112	0	0	21
28.0	69	313	329	112	112	0	0	21
29.0	68	313	329	112	112	0	0	21
30.0	69	313	329	112	112	0	0	21
31.0	68	313	329	112	112	0	0	21
22.0	70	313	330	113	112	0	0	22
23.0	69	313	330	112	112	0	0	22
24.0	69	313	330	112	112	0	0	22
25.0	69	313	330	112	112	0	0	22
26.0	69	313	330	112	112	0	0	21
27.0	69	313	330	112	112	0	0	21
28.0	69	313	329	112	112	0	0	21
29.0	68	313	329	112	112	0	0	21
30.0	69	313	329	112	112	0	0	21
31.0	68	313	329	112	112	0	0	21

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.02
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION FLOW TEST

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.02

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
35.0	68	313	329	111	111	0	0	21
36.0	68	313	329	111	111	0	0	20
37.0	67	313	329	111	111	0	0	20
38.0	68	313	329	111	111	0	0	20
39.0	68	313	329	111	111	0	0	20
40.0	67	313	329	111	111	0	0	20
41.0	67	313	329	111	111	0	0	19
42.0	68	313	329	111	111	0	0	19
43.0	67	313	329	111	111	0	0	19
44.0	67	313	329	111	111	0	0	19
45.0	68	313	329	111	111	0	0	18
46.0	68	313	329	111	111	0	0	18
47.0	68	313	329	111	110	0	0	18
48.0	67	313	329	110	110	0	0	18
49.0	67	313	329	110	110	0	0	17
50.0	67	313	329	110	110	0	0	17
51.0	67	313	329	110	110	0	0	17
52.0	67	313	329	110	110	0	0	17
53.0	67	313	329	110	110	0	0	17
54.0	67	313	329	110	110	0	0	17
55.0	67	313	329	110	110	0	0	17
56.0	67	313	329	110	110	0	0	4
57.0	67	313	329	110	110	0	0	0
58.0	67	313	329	110	110	0	0	0
59.0	66	313	329	110	110	0	0	0
60.0	67	313	329	110	110	0	0	0
61.0	67	313	329	110	110	0	0	0
62.0	67	313	329	110	110	0	0	0
63.0	67	313	329	110	109	0	0	0
64.0	67	313	329	109	109	0	0	0
65.0	67	313	329	109	109	0	0	0
66.0	67	313	329	109	109	0	0	0
67.0	67	313	329	109	109	0	0	0
68.0	67	313	329	109	109	0	0	0
69.0	67	313	329	109	109	0	0	0
70.0	67	313	329	109	109	0	0	0
71.0	67	313	329	109	109	0	0	0
72.0	67	313	329	109	109	0	0	0
73.0	67	313	329	109	109	0	0	0
74.0	67	313	329	109	109	0	0	0
75.0	67	313	329	109	109	0	0	0
76.0	67	313	329	109	109	0	0	0
77.0	67	313	329	109	109	0	0	0
78.0	66	313	329	109	109	0	0	0
79.0	68	313	329	109	109	0	0	0
80.0	67	313	329	109	109	0	0	0
81.0	67	313	329	109	109	0	0	0
82.0	67	313	329	109	108	0	0	0
83.0	67	313	329	109	108	0	0	0
84.0	67	313	329	109	108	0	0	0
85.0	67	313	329	108	108	0	0	0
86.0	67	313	329	108	108	0	0	0
87.0	67	313	329	108	108	0	0	0
88.0	67	313	329	108	108	0	0	0
89.0	67	313	329	108	108	0	0	0
90.0	67	313	329	108	108	0	0	0
91.0	67	313	329	108	108	0	0	0
92.0	67	313	329	108	108	0	0	0
93.0	67	313	329	108	108	0	0	0
94.0	67	313	329	108	108	0	0	0
95.0	67	313	329	108	108	0	0	0
96.0	67	313	329	108	108	0	0	0
97.0	67	313	329	108	108	0	0	0
98.0	67	313	329	108	108	0	0	0
99.0	67	313	329	108	108	0	0	0
100.0	67	313	329	108	108	0	0	0
101.0	67	313	329	108	108	0	0	0
102.0	68	313	329	108	108	0	0	0
103.0	67	313	329	108	108	0	0	0
104.0	67	313	322	108	108	0	0	0
105.0	67	313	296	108	108	0	0	0
106.0	67	313	275	107	107	0	0	0

TEST NUMBER 243.02

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
107.0	68	313	256	107	107	0	0	0
108.0	67	313	240	107	107	0	0	0
109.0	67	313	226	107	107	0	0	0
110.0	67	313	212	106	106	0	0	0
111.0	67	313	200	106	106	0	0	0
112.0	67	313	188	106	105	0	0	0
113.0	67	313	178	105	105	0	0	0
114.0	68	313	168	105	104	0	0	0
115.0	66	313	159	104	104	0	0	0

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.03
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION FLOW TEST

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.03

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	65	313	12	12	12	0	0	30
-8.0	65	313	12	12	12	0	0	30
-7.0	65	313	12	12	13	0	0	30
-6.0	65	313	12	12	13	0	0	30
-5.0	65	313	12	12	13	0	0	30
-4.0	65	313	12	12	12	0	0	30
-3.0	65	313	12	12	12	0	0	30
-2.0	64	313	12	12	12	0	0	30
-1.0	65	313	12	12	12	0	0	30
0.0	65	321	12	12	13	0	0	30
1.0	65	313	328	19	38	0	0	39
2.0	69	305	324	71	88	0	0	40
3.0	73	313	329	107	106	0	0	35
4.0	73	313	329	109	110	0	0	31
5.0	73	313	329	111	110	0	0	31
6.0	73	313	328	112	112	0	0	31
7.0	73	313	328	112	112	0	0	30
8.0	72	313	328	113	113	0	0	30
9.0	72	313	328	113	113	0	0	29
10.0	72	313	328	113	113	0	0	29
11.0	72	313	328	113	113	0	0	28
12.0	69	313	328	113	114	0	0	28
13.0	70	313	328	113	113	0	0	28
14.0	69	313	328	113	113	0	0	27
15.0	69	313	328	113	113	0	0	27
16.0	69	313	328	113	112	0	0	27
17.0	69	313	328	113	112	0	0	27
18.0	69	313	328	112	112	0	0	26
19.0	68	313	328	112	112	0	0	26
20.0	69	313	328	112	112	0	0	26
21.0	68	313	328	112	112	0	0	25
22.0	68	313	328	112	111	0	0	26
23.0	67	313	328	111	111	0	0	25
24.0	67	313	328	111	111	0	0	25
25.0	68	313	328	111	111	0	0	25
26.0	68	313	328	111	111	0	0	25
27.0	67	313	328	111	111	0	0	24
28.0	67	313	328	111	110	0	0	24
29.0	67	313	328	110	110	0	0	24
30.0	68	313	328	110	110	0	0	24
31.0	67	313	328	110	110	0	0	24
32.0	67	313	328	110	110	0	0	24
33.0	66	313	328	110	110	0	0	24
34.0	67	313	328	110	110	0	0	24
35.0	67	313	328	109	109	0	0	24
36.0	66	313	328	109	109	0	0	24
37.0	67	313	328	109	109	0	0	24
38.0	66	313	328	109	109	0	0	24
39.0	67	313	328	109	109	0	0	24
40.0	66	313	328	109	109	0	0	24
41.0	67	313	328	109	108	0	0	24
42.0	67	313	328	109	108	0	0	24
43.0	66	313	328	108	108	0	0	24
44.0	66	313	328	108	108	0	0	24
45.0	66	313	328	108	108	0	0	24
46.0	66	313	328	108	108	0	0	24
47.0	66	313	328	108	108	0	0	24
48.0	66	313	328	108	108	0	0	25
49.0	67	313	328	107	108	0	0	25
50.0	67	313	329	107	107	0	0	25
51.0	66	313	328	107	107	0	0	26
52.0	66	313	328	107	107	0	0	26
53.0	66	313	328	107	107	0	0	26
54.0	66	313	328	107	107	0	0	27
55.0	67	313	328	107	107	0	0	27
56.0	67	313	328	106	107	0	0	27
57.0	67	313	327	106	106	0	0	27
58.0	66	313	328	106	106	0	0	27
59.0	67	313	328	106	106	0	0	27
60.0	67	313	328	106	106	0	0	27
61.0	66	313	327	106	107	0	0	28
62.0	67	313	327	107	107	0	0	28

TEST NUMBER 243.03

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	66	313	328	107	107	0	0	28
64.0	67	313	327	107	107	0	0	28
65.0	67	313	316	108	108	0	0	29
66.0	67	313	276	108	108	0	0	29
67.0	66	313	244	108	108	0	0	29
68.0	67	313	217	109	108	0	0	29
69.0	67	313	192	109	109	0	0	29
70.0	67	313	170	109	108	0	0	30
71.0	66	313	150	108	108	0	0	30
72.0	67	313	133	108	108	0	0	30
73.0	67	313	120	108	108	0	0	30
74.0	66	313	112	107	107	0	0	31
75.0	66	313	108	106	107	0	0	31
76.0	67	313	106	106	106	0	0	32

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.04
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.04

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	65	313	12	12	12	0	0	30
-8.0	65	313	12	12	12	0	0	30
-7.0	66	313	12	12	13	0	0	30
-6.0	65	313	12	12	13	0	0	30
-5.0	65	313	12	12	12	0	0	30
-4.0	65	313	12	12	12	0	0	30
-3.0	65	313	12	12	12	0	0	30
-2.0	65	313	12	12	12	0	0	30
-1.0	66	313	12	12	12	0	0	30
0.0	64	313	12	12	12	0	0	30
1.0	65	313	326	19	39	0	0	39
2.0	69	313	324	73	86	0	0	39
3.0	72	313	327	107	108	0	0	36
4.0	73	313	327	112	112	0	0	32
5.0	73	313	327	114	114	0	0	31
6.0	73	305	327	115	115	0	0	31
7.0	73	313	326	115	115	0	0	30
8.0	73	313	326	116	115	0	0	28
9.0	73	313	326	116	115	0	0	27
10.0	72	313	326	115	115	0	0	27
11.0	70	313	326	115	115	0	0	27
12.0	70	313	326	115	115	0	0	27
13.0	70	305	326	115	115	0	0	26
14.0	70	313	326	114	114	0	0	26
15.0	69	313	326	114	114	0	0	25
16.0	69	313	326	114	114	0	0	25
17.0	69	313	326	114	114	0	0	24
18.0	69	313	326	113	113	0	0	24
19.0	68	313	326	113	113	0	0	23
20.0	69	313	326	113	113	0	0	23
21.0	68	313	326	113	113	0	0	23
22.0	67	313	326	113	113	0	0	22
23.0	68	313	326	113	112	0	0	22
24.0	68	313	326	113	112	0	0	22
25.0	67	313	326	112	112	0	0	21
26.0	68	313	326	112	112	0	0	21
27.0	68	305	326	112	112	0	0	21
28.0	67	313	326	112	112	0	0	21
29.0	66	313	326	112	112	0	0	21
30.0	67	313	326	112	112	0	0	21
31.0	67	313	326	112	112	0	0	20
32.0	67	313	312	112	111	0	0	20
33.0	67	313	288	111	111	0	0	20
34.0	67	313	268	111	111	0	0	20
35.0	67	313	250	111	111	0	0	20
36.0	66	313	235	110	110	0	0	20
37.0	67	313	221	110	110	0	0	19
38.0	67	313	208	109	109	0	0	19
39.0	66	313	196	109	109	0	0	19
40.0	66	313	185	108	108	0	0	19
41.0	66	313	175	108	108	0	0	19
42.0	66	305	165	107	107	0	0	19
43.0	66	313	157	106	106	0	0	19

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.05
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.05

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.3 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	64	305	12	12	12	0	0	30
-8.0	64	297	12	12	12	0	0	30
-7.0	64	297	12	12	12	0	0	30
-6.0	64	297	12	12	12	0	0	30
-5.0	64	297	12	12	12	0	0	30
-4.0	64	305	12	12	13	0	0	30
-3.0	64	297	12	12	12	0	0	30
-2.0	65	297	12	12	12	0	0	30
-1.0	64	297	12	12	12	0	0	30
0.0	64	297	12	12	12	0	0	30
1.0	64	297	317	13	14	0	0	30
2.0	64	297	317	15	15	0	0	30
3.0	64	297	317	16	17	0	0	30
4.0	65	297	316	18	19	0	0	30
5.0	65	297	316	20	20	0	0	30
6.0	65	297	316	22	22	0	0	30
7.0	65	297	316	24	24	0	0	30
8.0	66	297	315	25	25	0	0	30
9.0	66	297	315	26	26	0	0	29
10.0	66	297	315	27	27	0	0	27
11.0	66	297	315	28	28	0	0	25
12.0	66	297	315	28	28	0	0	22
13.0	66	297	315	29	29	0	0	18
14.0	67	305	315	30	30	0	0	14
15.0	67	297	315	30	30	0	0	8
16.0	67	297	315	31	31	0	0	0
17.0	66	297	315	32	32	0	0	0
18.0	66	305	315	32	32	0	0	0
19.0	68	297	315	33	33	0	0	0
20.0	67	305	315	33	34	0	0	0
21.0	66	297	315	34	34	0	0	0
22.0	67	305	315	35	35	0	0	0
23.0	66	297	315	35	35	0	0	0
24.0	67	297	315	36	36	0	0	0
25.0	67	297	315	37	37	0	0	0
26.0	67	297	315	37	37	0	0	0
27.0	67	297	315	38	38	0	0	0
28.0	67	297	315	38	38	0	0	0
29.0	67	305	315	39	39	0	0	0
30.0	67	297	315	39	39	0	0	0
31.0	67	297	315	40	40	0	0	0
32.0	68	305	315	40	41	0	0	0
33.0	67	297	315	41	41	0	0	0
34.0	67	305	315	42	42	0	0	0
35.0	67	297	315	42	42	0	0	0
36.0	68	297	315	43	43	0	0	0
37.0	67	297	315	43	43	0	0	0
38.0	68	305	315	44	44	0	0	0
39.0	67	297	315	44	44	0	0	0
40.0	67	297	315	45	45	0	0	0
41.0	67	297	315	45	45	0	0	0
42.0	67	305	315	46	46	0	0	0
43.0	68	305	315	46	46	0	0	0
44.0	67	297	315	46	46	0	0	0
45.0	68	305	315	47	47	0	0	0
46.0	68	297	315	47	47	0	0	0
47.0	67	297	315	48	48	0	0	0
48.0	67	305	315	48	48	0	0	0
49.0	67	297	315	49	49	0	0	0
50.0	67	305	315	49	49	0	0	0
51.0	66	297	315	50	49	0	0	0
52.0	67	297	315	50	50	0	0	0
53.0	69	297	315	50	50	0	0	0
54.0	68	297	315	51	51	0	0	0
55.0	67	297	315	51	51	0	0	0
56.0	67	305	315	52	52	0	0	0
57.0	67	297	315	52	52	0	0	0
58.0	69	297	315	52	53	0	0	0
59.0	68	297	315	53	53	0	0	0
60.0	67	297	315	53	53	0	0	0
61.0	68	305	315	53	54	0	0	0
62.0	67	297	314	54	54	0	0	0

TEST NUMBER 243.05

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	67	305	314	54	54	0	0	0
64.0	68	297	314	55	55	0	0	0
65.0	67	297	314	55	55	0	0	0
66.0	67	297	314	55	56	0	0	0
67.0	67	305	314	56	56	0	0	0
68.0	68	297	314	56	56	0	0	0
69.0	67	297	314	56	56	0	0	0
70.0	68	297	314	57	57	0	0	0
71.0	67	297	314	57	57	0	0	0
72.0	68	297	314	57	57	0	0	0
73.0	67	297	314	58	58	0	0	0
74.0	68	305	314	58	58	0	0	0
75.0	68	297	314	58	58	0	0	0
76.0	67	297	314	59	59	0	0	0
77.0	67	297	314	59	59	0	0	0
78.0	67	297	314	59	59	0	0	0
79.0	67	297	314	60	60	0	0	0
80.0	67	297	314	60	60	0	0	0
81.0	67	297	314	60	60	0	0	0
82.0	67	297	314	61	60	0	0	0
83.0	67	297	314	61	61	0	0	0
84.0	67	305	314	61	61	0	0	0
85.0	67	297	314	61	61	0	0	0
86.0	67	297	314	61	61	0	0	0
87.0	67	297	314	62	62	0	0	0
88.0	66	305	314	62	62	0	0	0
89.0	67	297	314	62	62	0	0	0
90.0	67	297	314	63	63	0	0	0
91.0	67	297	314	63	63	0	0	0
92.0	67	297	314	63	63	0	0	0
93.0	67	297	314	63	63	0	0	0
94.0	67	297	314	63	64	0	0	0
95.0	67	297	314	64	64	0	0	0
96.0	66	297	314	64	64	0	0	0
97.0	67	305	314	64	64	0	0	0
98.0	67	297	314	64	64	0	0	0
99.0	67	297	314	65	65	0	0	0
100.0	66	297	301	65	65	0	0	0
101.0	67	297	277	65	65	0	0	0
102.0	67	297	258	65	65	0	0	0
103.0	67	297	241	65	65	0	0	0
104.0	67	305	226	65	65	0	0	0
105.0	67	305	212	65	65	0	0	0
106.0	67	297	199	65	65	0	0	0
107.0	67	297	187	65	65	0	0	0
108.0	67	297	176	64	65	0	0	0
109.0	67	297	165	64	64	0	0	0
110.0	66	305	155	64	64	0	0	0
111.0	67	297	146	64	64	0	0	0

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.06
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, SS TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.06

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	64	297	12	12	12	0	0	30
-8.0	63	297	12	12	13	0	0	30
-7.0	64	297	12	12	13	0	0	30
-6.0	63	297	12	12	12	0	0	30
-5.0	64	297	12	12	13	0	0	30
-4.0	63	297	12	12	13	0	0	30
-3.0	63	297	12	12	12	0	0	30
-2.0	63	297	12	12	12	0	0	30
-1.0	63	297	12	12	12	0	0	30
0.0	64	297	12	12	13	0	0	30
1.0	64	297	312	23	43	0	0	39
2.0	68	297	310	76	86	0	0	39
3.0	70	297	313	106	107	0	0	36
4.0	72	297	313	111	112	0	0	32
5.0	72	297	313	113	113	0	0	32
6.0	73	297	313	114	114	0	0	31
7.0	72	297	313	115	115	0	0	30
8.0	72	297	312	115	115	0	0	29
9.0	70	297	312	115	115	0	0	29
10.0	69	297	312	115	115	0	0	28
11.0	69	297	312	115	115	0	0	27
12.0	69	297	312	114	114	0	0	27
13.0	69	297	312	114	114	0	0	27
14.0	68	297	312	113	113	0	0	27
15.0	68	297	312	113	113	0	0	26
16.0	67	297	312	113	113	0	0	26
17.0	67	297	312	112	112	0	0	25
18.0	68	297	312	112	112	0	0	25
19.0	67	297	312	112	112	0	0	25
20.0	67	297	312	112	111	0	0	24
21.0	67	297	312	111	111	0	0	24
22.0	66	297	312	111	111	0	0	24
23.0	67	297	312	111	111	0	0	24
24.0	66	297	312	110	110	0	0	24
25.0	67	297	312	110	110	0	0	24
26.0	66	297	312	110	110	0	0	24
27.0	66	297	312	109	109	0	0	24
28.0	66	289	312	109	109	0	0	24
29.0	66	297	312	109	109	0	0	24
30.0	66	297	312	108	108	0	0	24
31.0	66	289	312	108	108	0	0	24
32.0	66	297	312	108	108	0	0	24
33.0	65	297	312	108	108	0	0	24
34.0	66	297	312	107	108	0	0	24
35.0	66	297	312	107	107	0	0	24
36.0	66	297	312	107	107	0	0	24
37.0	66	297	307	106	106	0	0	24
38.0	66	297	284	106	106	0	0	25
39.0	66	297	265	106	106	0	0	25
40.0	65	297	249	106	105	0	0	25
41.0	66	297	234	105	105	0	0	26
42.0	65	297	221	104	104	0	0	27
43.0	66	297	209	104	104	0	0	27
44.0	66	297	195	103	103	0	0	28
45.0	65	297	176	103	103	0	0	29
46.0	65	297	153	103	103	0	0	30
47.0	66	297	123	103	103	0	0	32
48.0	65	297	104	103	103	0	0	33

TEST DATE = 02/21/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.07
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, SS TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.07

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.3 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	64	297	12	12	12	0	0	30
-8.0	64	297	12	12	12	0	0	30
-7.0	65	297	12	12	13	0	0	30
-6.0	64	297	12	12	13	0	0	30
-5.0	64	297	12	12	13	0	0	30
-4.0	64	297	12	12	13	0	0	30
-3.0	65	297	12	12	12	0	0	30
-2.0	64	297	12	12	13	0	0	30
-1.0	66	297	12	12	13	0	0	30
0.0	64	297	12	12	12	0	0	30
1.0	64	297	314	14	14	0	0	30
2.0	65	297	314	15	16	0	0	30
3.0	65	297	313	17	17	0	0	30
4.0	66	289	313	19	20	0	0	30
5.0	66	297	313	21	22	0	0	30
6.0	65	297	313	23	24	0	0	30
7.0	66	297	313	25	25	0	0	30
8.0	66	289	313	26	26	0	0	29
9.0	65	289	312	27	27	0	0	27
10.0	66	297	312	27	28	0	0	25
11.0	67	297	312	28	28	0	0	22
12.0	67	297	312	29	29	0	0	20
13.0	67	297	312	29	29	0	0	15
14.0	67	297	312	30	30	0	0	10
15.0	66	297	312	31	31	0	0	3
16.0	67	297	312	31	32	0	0	0
17.0	66	297	312	31	32	0	0	0
18.0	66	297	312	32	32	0	0	0
19.0	67	297	312	33	33	0	0	0
20.0	66	297	312	33	34	0	0	0
21.0	66	297	312	34	34	0	0	0
22.0	66	297	312	34	35	0	0	0
23.0	67	297	312	35	35	0	0	0
24.0	67	297	312	36	36	0	0	0
25.0	66	289	312	36	36	0	0	0
26.0	66	289	312	37	37	0	0	0
27.0	68	289	312	37	37	0	0	0
28.0	67	297	312	38	38	0	0	0
29.0	67	297	312	38	39	0	0	0
30.0	66	297	312	39	39	0	0	0
31.0	67	297	312	39	40	0	0	0
32.0	66	297	312	40	40	0	0	0
33.0	67	297	312	40	41	0	0	0
34.0	67	289	312	41	41	0	0	0
35.0	66	297	312	41	42	0	0	0
36.0	67	297	312	42	42	0	0	0
37.0	67	297	312	42	42	0	0	0
38.0	68	297	292	43	43	0	0	0
39.0	67	297	269	43	43	0	0	0
40.0	67	297	251	43	43	0	0	0
41.0	67	297	234	44	44	0	0	0
42.0	66	297	220	44	44	0	0	0
43.0	67	297	206	44	44	0	0	0
44.0	66	297	194	44	44	0	0	0
45.0	67	289	182	44	44	0	0	0
46.0	66	289	171	44	45	0	0	0
47.0	67	297	161	44	44	0	0	0
48.0	66	297	151	44	44	0	0	0
49.0	66	297	142	44	44	0	0	0

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.08
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, SS TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.08

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.3 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	56	321	12	12	13	0	0	30
-8.0	57	321	12	12	13	0	0	30
-7.0	57	330	12	12	13	0	0	30
-6.0	56	321	12	12	13	0	0	30
-5.0	57	330	12	12	13	0	0	30
-4.0	57	321	12	12	13	0	0	30
-3.0	56	321	12	12	13	0	0	30
-2.0	56	321	12	12	13	0	0	30
-1.0	56	330	13	12	13	0	0	30
0.0	56	330	12	12	12	0	0	30
1.0	56	321	340	21	49	0	0	39
2.0	62	321	295	133	193	0	0	51
3.0	66	321	327	262	272	0	0	46
4.0	68	321	339	292	295	0	0	36
5.0	67	321	339	294	295	0	0	34
6.0	65	321	338	296	298	0	0	34
7.0	64	321	338	297	298	0	0	33
8.0	62	321	338	297	298	0	0	33
9.0	60	321	338	297	298	0	0	33
10.0	59	321	338	296	297	0	0	33
11.0	57	321	338	296	297	0	0	33
12.0	57	321	338	295	296	0	0	33
13.0	55	321	338	295	295	0	0	33
14.0	54	321	338	294	295	0	0	33
15.0	53	321	338	294	295	0	0	33
16.0	53	321	338	293	294	0	0	33
17.0	52	321	338	293	293	0	0	33
18.0	52	321	338	293	293	0	0	33
19.0	51	321	338	293	292	0	0	33
20.0	51	321	338	292	293	0	0	33
21.0	51	321	338	292	293	0	0	33
22.0	51	321	338	292	292	0	0	33
23.0	51	321	338	291	292	0	0	33
24.0	51	321	338	292	292	0	0	33
25.0	51	321	338	292	293	0	0	33
26.0	50	321	338	293	294	0	0	33
27.0	50	321	338	294	295	0	0	33
28.0	50	321	338	295	296	0	0	33
29.0	51	321	338	296	297	0	0	33
30.0	50	321	338	297	297	0	0	33
31.0	51	321	338	297	298	0	0	33
32.0	50	321	338	297	297	0	0	33
33.0	51	313	338	296	297	0	0	33
34.0	49	321	338	295	296	0	0	33
35.0	51	321	338	295	296	0	0	33
36.0	50	313	338	295	296	0	0	33
37.0	49	321	338	294	295	0	0	33
38.0	49	321	338	293	294	0	0	33
39.0	48	313	338	293	294	0	0	32
40.0	50	321	338	292	293	0	0	33
41.0	50	321	338	292	293	0	0	33
42.0	49	313	338	292	293	0	0	33
43.0	49	321	337	292	292	0	0	33
44.0	50	313	337	292	293	0	0	33
45.0	50	321	337	292	293	0	0	33
46.0	49	321	337	294	295	0	0	33
47.0	50	313	337	295	296	0	0	33
48.0	50	321	337	296	297	0	0	33
49.0	50	313	337	297	297	0	0	33
50.0	50	321	337	296	297	0	0	32
51.0	49	321	337	295	296	0	0	33
52.0	49	321	337	295	296	0	0	32
53.0	49	321	337	294	295	0	0	32
54.0	50	321	337	293	294	0	0	32
55.0	49	321	337	293	294	0	0	32
56.0	49	313	337	292	293	0	0	32
57.0	50	321	337	292	293	0	0	32
58.0	50	321	337	292	292	0	0	32
59.0	50	321	337	291	292	0	0	32
60.0	49	321	337	292	292	0	0	33
61.0	50	313	337	293	293	0	0	33
62.0	49	321	337	294	294	0	0	33

TEST NUMBER 243.08

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	50	321	337	294	295	0	0	33
64.0	50	321	337	295	296	0	0	33
65.0	50	321	337	296	297	0	0	33
66.0	51	321	337	297	297	0	0	33
67.0	49	321	337	297	298	0	0	33
68.0	50	321	337	296	297	0	0	32
69.0	50	321	337	295	296	0	0	32
70.0	49	321	337	294	294	0	0	32
71.0	50	321	337	292	292	0	0	21
72.0	49	321	337	298	289	0	0	5
73.0	49	321	337	286	286	0	0	0
74.0	49	321	337	283	284	0	0	0
75.0	49	321	337	281	282	0	0	0
76.0	48	321	321	278	279	0	0	0
77.0	49	321	307	276	276	0	0	0
78.0	48	321	297	273	273	0	0	0
79.0	49	321	289	270	271	0	0	0
80.0	48	321	282	267	268	0	0	0
81.0	47	321	277	265	265	0	0	0
82.0	48	321	273	262	263	0	0	0
83.0	48	321	268	259	260	0	0	0
84.0	47	321	265	257	257	0	0	0
85.0	47	321	261	254	255	0	0	0
86.0	48	321	258	251	252	0	0	0

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.09
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, MONEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.09

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	59	321	13	12	13	0	0	30
-8.0	59	321	12	12	13	0	0	30
-7.0	59	321	12	12	12	0	0	30
-6.0	59	321	12	12	13	0	0	30
-5.0	60	321	12	12	13	0	0	30
-4.0	59	321	12	12	13	0	0	30
-3.0	59	321	13	12	13	0	0	30
-2.0	59	321	12	12	13	0	0	30
-1.0	59	321	12	12	13	0	0	30
0.0	59	321	12	12	13	0	0	30
1.0	59	321	338	17	34	0	0	38
2.0	63	321	292	113	180	0	0	51
3.0	68	321	318	251	265	0	0	48
4.0	69	313	334	291	291	0	0	36
5.0	69	321	334	293	295	0	0	33
6.0	68	313	333	295	296	0	0	33
7.0	66	313	333	296	297	0	0	33
8.0	64	321	333	297	298	0	0	33
9.0	63	313	333	297	297	0	0	33
10.0	62	321	333	296	297	0	0	32
11.0	60	313	333	295	296	0	0	32
12.0	59	313	333	295	295	0	0	32
13.0	59	313	333	294	295	0	0	32
14.0	57	313	333	293	293	0	0	32
15.0	57	321	333	292	293	0	0	32
16.0	56	313	333	292	293	0	0	32
17.0	54	313	333	291	292	0	0	32
18.0	55	313	333	291	291	0	0	32
19.0	53	321	333	291	292	0	0	32
20.0	54	313	332	291	292	0	0	33
21.0	53	313	333	292	293	0	0	33
22.0	53	313	332	293	294	0	0	33
23.0	53	313	332	294	295	0	0	33
24.0	53	313	332	294	295	0	0	33
25.0	53	313	332	295	296	0	0	33
26.0	52	313	332	296	297	0	0	33
27.0	53	313	332	297	297	0	0	33
28.0	53	321	332	297	297	0	0	33
29.0	53	313	332	296	297	0	0	32
30.0	53	313	332	296	296	0	0	32
31.0	53	313	332	295	296	0	0	32
32.0	52	321	332	295	295	0	0	32
33.0	52	313	332	294	295	0	0	32
34.0	52	313	332	293	294	0	0	32
35.0	52	313	332	293	294	0	0	32
36.0	51	313	332	292	293	0	0	32
37.0	52	313	332	292	293	0	0	32
38.0	51	313	332	291	292	0	0	32
39.0	51	313	332	291	292	0	0	32
40.0	51	313	332	292	292	0	0	33
41.0	51	313	332	292	293	0	0	33
42.0	51	313	291	290	291	0	0	33
43.0	50	313	288	288	288	0	0	36
44.0	51	313	286	285	286	0	0	40
45.0	51	313	283	282	283	0	0	46
46.0	50	313	281	280	281	0	0	55
47.0	51	313	278	277	278	0	0	65
48.0	50	313	276	275	276	0	0	80
49.0	50	313	273	273	273	0	0	91
50.0	50	313	271	270	271	0	0	91
51.0	50	321	269	268	269	0	0	91
52.0	50	313	266	266	266	0	0	91
53.0	49	313	264	263	265	0	0	91

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.1
TEST DESCRIPTION NAVY TUBE FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.1

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	59	321	13	12	13	0	0	30
-8.0	59	321	12	12	13	0	0	30
-7.0	59	313	12	12	13	0	0	30
-6.0	59	313	13	12	13	0	0	30
-5.0	59	321	12	12	13	0	0	30
-4.0	60	313	12	12	13	0	0	30
-3.0	59	321	13	12	13	0	0	30
-2.0	59	313	12	12	13	0	0	30
-1.0	60	313	12	12	13	0	0	30
0.0	59	321	13	12	13	0	0	30
1.0	57	313	336	13	14	0	0	30
2.0	59	313	335	15	15	0	0	30
3.0	60	313	335	16	17	0	0	30
4.0	59	313	334	18	19	0	0	30
5.0	60	313	334	20	21	0	0	30
6.0	59	321	334	22	22	0	0	30
7.0	60	313	334	24	24	0	0	30
8.0	59	313	334	25	25	0	0	29
9.0	59	313	334	25	26	0	0	27
10.0	59	321	334	26	26	0	0	26
11.0	59	321	333	27	27	0	0	22
12.0	60	313	334	27	28	0	0	19
13.0	60	313	333	28	28	0	0	15
14.0	60	313	333	29	29	0	0	9
15.0	57	321	333	30	30	0	0	3
16.0	60	313	333	30	31	0	0	0
17.0	60	313	333	31	31	0	0	0
18.0	60	321	333	31	32	0	0	0
19.0	60	313	333	32	33	0	0	0
20.0	59	313	333	33	34	0	0	0
21.0	59	313	333	33	34	0	0	0
22.0	57	313	333	34	35	0	0	0
23.0	56	313	333	35	35	0	0	0
24.0	57	313	333	35	36	0	0	0
25.0	57	313	333	36	36	0	0	0
26.0	56	313	333	36	37	0	0	0
27.0	57	313	333	37	38	0	0	0
28.0	57	313	333	38	38	0	0	0
29.0	59	313	333	38	39	0	0	0
30.0	57	313	333	38	39	0	0	0
31.0	56	313	333	39	39	0	0	0
32.0	57	313	333	40	40	0	0	0
33.0	57	321	333	40	41	0	0	0
34.0	57	313	333	41	41	0	0	0
35.0	55	313	333	41	42	0	0	0
36.0	56	313	333	42	42	0	0	0
37.0	55	313	333	42	42	0	0	0
38.0	56	313	333	43	43	0	0	0
39.0	56	313	333	43	44	0	0	0
40.0	56	313	333	44	44	0	0	0
41.0	55	313	333	44	45	0	0	0
42.0	55	313	333	45	45	0	0	0
43.0	55	313	333	45	45	0	0	5
44.0	55	313	333	46	46	0	0	9
45.0	55	313	333	46	46	0	0	13
46.0	55	321	333	46	46	0	0	15
47.0	55	313	333	47	47	0	0	19
48.0	56	313	333	47	47	0	0	21
49.0	55	313	333	47	48	0	0	23
50.0	54	313	333	48	49	0	0	25
51.0	54	313	333	48	49	0	0	27
52.0	55	321	333	49	49	0	0	28
53.0	55	313	333	50	51	0	0	32
54.0	55	321	332	65	68	0	0	36
55.0	56	313	332	73	73	0	0	33
56.0	56	313	332	76	77	0	0	33
57.0	56	313	332	77	78	0	0	31
58.0	57	313	332	78	78	0	0	30
59.0	54	313	332	78	79	0	0	29
60.0	55	313	332	78	79	0	0	28
61.0	54	313	332	78	78	0	0	27
62.0	55	313	332	78	77	0	0	27

TEST NUMBER 243.1

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	55	313	332	78	78	0	0	25
64.0	55	313	332	78	78	0	0	24
65.0	54	313	332	78	78	0	0	29
66.0	53	313	332	82	82	0	0	33
67.0	55	313	332	89	90	0	0	33
68.0	55	313	275	96	96	0	0	33
69.0	56	313	199	97	97	0	0	32
70.0	55	321	166	97	98	0	0	31
71.0	55	313	150	97	97	0	0	30
72.0	54	313	141	96	97	0	0	28
73.0	54	313	135	95	95	0	0	27
74.0	53	313	130	94	94	0	0	27
75.0	54	313	125	93	94	0	0	27
76.0	53	313	121	92	93	0	0	27
77.0	53	313	117	91	91	0	0	27
78.0	53	313	114	91	91	0	0	27
79.0	52	313	110	90	90	0	0	27

TEST DATE =	02/22/85
PROGRAM ENGINEER'S NAME	HOMA
TEST NUMBER	243.11
TEST DESCRIPTION	NAVY TUBE FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.11

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.3 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	60	321	12	12	13	0	0	30
-8.0	59	313	12	12	13	0	0	30
-7.0	59	313	12	12	13	0	0	30
-6.0	59	313	13	12	13	0	0	30
-5.0	59	313	12	12	13	0	0	30
-4.0	59	321	13	12	13	0	0	30
-3.0	59	313	12	12	13	0	0	30
-2.0	60	321	12	12	13	0	0	30
-1.0	59	313	13	12	13	0	0	30
0.0	60	321	12	12	13	0	0	30
1.0	59	313	334	16	19	0	0	33
2.0	59	313	334	24	27	0	0	33
3.0	60	313	333	32	33	0	0	33
4.0	61	313	333	35	35	0	0	31
5.0	61	313	333	36	36	0	0	28
6.0	61	313	332	36	36	0	0	27
7.0	61	313	332	36	37	0	0	24
8.0	61	313	332	37	37	0	0	22
9.0	60	313	332	38	38	0	0	20
10.0	60	313	332	38	39	0	0	16
11.0	60	313	332	38	39	0	0	12
12.0	60	313	332	39	40	0	0	7
13.0	60	313	332	40	40	0	0	0
14.0	60	313	332	40	40	0	0	0
15.0	59	313	332	41	41	0	0	0
16.0	60	313	332	41	42	0	0	0
17.0	59	313	332	42	42	0	0	0
18.0	57	313	332	42	42	0	0	0
19.0	59	313	332	43	43	0	0	0
20.0	59	313	332	43	44	0	0	0
21.0	57	313	332	43	44	0	0	0
22.0	57	313	332	44	44	0	0	0
23.0	57	313	332	44	45	0	0	0
24.0	57	313	332	45	45	0	0	2
25.0	56	313	332	45	45	0	0	3
26.0	56	313	332	46	46	0	0	4
27.0	56	313	332	46	47	0	0	5
28.0	56	313	332	46	47	0	0	7
29.0	56	313	332	47	47	0	0	7
30.0	55	313	332	47	47	0	0	8
31.0	55	313	332	47	47	0	0	15
32.0	55	313	332	48	48	0	0	23
33.0	55	313	332	49	49	0	0	31
34.0	56	313	331	54	55	0	0	33
35.0	56	313	331	61	61	0	0	33
36.0	57	313	331	66	67	0	0	33
37.0	57	313	331	68	69	0	0	31
38.0	57	313	331	68	69	0	0	29
39.0	57	313	331	69	69	0	0	29
40.0	56	313	331	70	70	0	0	29
41.0	56	313	331	70	70	0	0	29
42.0	56	313	331	71	72	0	0	29
43.0	55	313	331	72	72	0	0	29
44.0	56	313	331	73	74	0	0	29
45.0	55	313	294	73	74	0	0	29
46.0	55	313	254	74	74	0	0	29
47.0	55	313	223	74	74	0	0	30
48.0	56	313	197	74	74	0	0	30
49.0	55	313	175	74	74	0	0	30
50.0	55	313	156	74	75	0	0	30
51.0	54	313	139	74	74	0	0	30
52.0	55	313	124	74	74	0	0	30
53.0	54	313	112	73	74	0	0	30
54.0	54	313	101	73	73	0	0	30
55.0	54	313	92	72	72	0	0	30
56.0	54	313	85	72	71	0	0	30

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.12
TEST DESCRIPTION NAVY TUBE DOWNWARD FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9538	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.12

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	57	321	13	12	13	0	0	30
-8.0	59	313	12	12	13	0	0	30
-7.0	59	313	12	12	12	0	0	30
-6.0	57	321	13	12	13	0	0	30
-5.0	57	321	13	12	12	0	0	30
-4.0	59	313	13	12	12	0	0	30
-3.0	59	313	12	12	13	0	0	30
-2.0	57	313	12	12	12	0	0	30
-1.0	59	313	12	12	13	0	0	30
0.0	57	313	13	12	13	0	0	30
1.0	59	313	334	13	14	0	0	30
2.0	59	313	334	15	15	0	0	30
3.0	57	313	333	16	17	0	0	30
4.0	59	313	333	18	18	0	0	30
5.0	59	313	332	19	20	0	0	30
6.0	59	313	332	21	21	0	0	30
7.0	60	313	332	22	23	0	0	30
8.0	60	313	332	24	25	0	0	29
9.0	59	313	332	24	25	0	0	28
10.0	60	313	332	25	26	0	0	27
11.0	60	313	332	26	26	0	0	25
12.0	60	313	332	26	27	0	0	23
13.0	60	313	332	27	28	0	0	21
14.0	59	313	332	28	28	0	0	17
15.0	60	313	332	28	29	0	0	14
16.0	59	313	332	29	29	0	0	13
17.0	60	313	332	30	31	0	0	13
18.0	59	313	332	30	31	0	0	13
19.0	60	313	332	31	31	0	0	13
20.0	59	313	332	31	32	0	0	13
21.0	59	313	331	32	32	0	0	13
22.0	59	313	331	32	33	0	0	13
23.0	59	313	331	33	34	0	0	13
24.0	60	313	331	34	34	0	0	13
25.0	57	313	331	34	35	0	0	13
26.0	57	313	331	35	35	0	0	12
27.0	57	313	331	35	36	0	0	12
28.0	57	313	331	36	36	0	0	13
29.0	59	313	331	37	37	0	0	15
30.0	57	313	331	37	37	0	0	16
31.0	57	313	331	38	38	0	0	17
32.0	56	313	331	38	39	0	0	18
33.0	59	321	331	39	39	0	0	19
34.0	57	313	331	39	39	0	0	19
35.0	59	313	331	40	40	0	0	20
36.0	56	313	331	40	40	0	0	20
37.0	57	313	331	41	41	0	0	20
38.0	56	313	331	41	41	0	0	22
39.0	56	313	331	42	42	0	0	29
40.0	56	313	331	46	47	0	0	33
41.0	57	313	331	53	54	0	0	33
42.0	60	313	331	60	60	0	0	33
43.0	59	313	331	62	63	0	0	31
44.0	59	313	331	62	63	0	0	28
45.0	59	313	331	62	63	0	0	27
46.0	59	313	331	62	63	0	0	24
47.0	55	313	331	63	63	0	0	21
48.0	57	313	331	63	63	0	0	19
49.0	56	313	331	63	63	0	0	16
50.0	56	313	331	63	63	0	0	16
51.0	56	313	331	63	64	0	0	16
52.0	56	313	331	64	64	0	0	16
53.0	56	313	331	64	65	0	0	17
54.0	56	313	331	64	65	0	0	18
55.0	55	313	331	64	65	0	0	18
56.0	56	313	331	64	65	0	0	18
57.0	56	313	331	65	65	0	0	19
58.0	55	313	331	65	65	0	0	19
59.0	57	313	331	65	65	0	0	20
60.0	55	321	331	65	66	0	0	20
61.0	55	313	331	65	66	0	0	26
62.0	55	313	331	67	67	0	0	33

TEST NUMBER 243.12

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	55	313	330	75	76	0	0	34
64.0	56	313	330	81	82	0	0	33
65.0	56	313	330	84	84	0	0	32
66.0	56	313	330	85	85	0	0	30
67.0	56	313	330	85	85	0	0	28
68.0	57	313	330	85	86	0	0	27
69.0	56	313	330	85	85	0	0	26
70.0	56	313	330	84	85	0	0	25
71.0	56	313	330	84	84	0	0	13
72.0	56	313	306	84	85	0	0	0
73.0	55	313	283	84	84	0	0	0
74.0	55	313	263	84	83	0	0	0
75.0	55	313	246	83	84	0	0	0
76.0	55	313	231	83	83	0	0	0
77.0	54	313	217	83	83	0	0	0
78.0	55	313	204	82	82	0	0	0
79.0	54	313	192	82	82	0	0	0
80.0	55	313	181	81	81	0	0	0
81.0	54	313	170	81	81	0	0	0
82.0	55	313	160	80	81	0	0	0
83.0	54	313	151	80	80	0	0	0

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.13
TEST DESCRIPTION NAVY TUBE DOWNWARD FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.13

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	61	321	12	12	13	0	0	29
-8.0	60	321	13	12	13	0	0	29
-7.0	60	313	12	12	13	0	0	29
-6.0	60	321	12	12	12	0	0	30
-5.0	60	321	13	12	12	0	0	30
-4.0	60	313	12	12	13	0	0	30
-3.0	60	313	13	12	12	0	0	30
-2.0	60	321	13	12	13	0	0	29
-1.0	60	313	13	12	12	0	0	30
0.0	60	321	12	12	13	0	0	30
1.0	60	321	337	14	14	0	0	30
2.0	60	313	336	16	16	0	0	31
3.0	61	313	336	19	19	0	0	31
4.0	60	313	335	21	22	0	0	31
5.0	62	313	335	24	24	0	0	31
6.0	61	313	335	26	26	0	0	30
7.0	61	313	335	26	26	0	0	27
8.0	61	313	334	27	27	0	0	25
9.0	61	313	334	28	28	0	0	23
10.0	61	313	334	28	29	0	0	20
11.0	61	313	334	29	29	0	0	15
12.0	60	313	334	29	29	0	0	10
13.0	60	313	334	30	31	0	0	4
14.0	60	313	334	31	31	0	0	0
15.0	61	313	334	31	31	0	0	0
16.0	61	321	334	32	32	0	0	0
17.0	60	313	334	32	33	0	0	0
18.0	60	313	334	33	33	0	0	0
19.0	59	313	334	33	34	0	0	0
20.0	60	313	334	34	35	0	0	0
21.0	59	321	334	34	35	0	0	0
22.0	60	313	334	35	35	0	0	0
23.0	59	321	334	35	35	0	0	0
24.0	60	321	334	36	36	0	0	0
25.0	60	313	334	36	37	0	0	0
26.0	59	313	334	37	38	0	0	0
27.0	59	321	334	38	38	0	0	0
28.0	59	313	334	38	39	0	0	0
29.0	59	313	334	38	39	0	0	2
30.0	59	313	334	39	40	0	0	3
31.0	59	313	334	39	40	0	0	3
32.0	59	313	334	40	40	0	0	3
33.0	60	313	334	40	41	0	0	3
34.0	59	313	334	41	41	0	0	3
35.0	59	313	334	41	42	0	0	3
36.0	57	313	334	42	42	0	0	3
37.0	59	313	334	42	42	0	0	3
38.0	57	313	334	42	42	0	0	6
39.0	57	313	334	43	43	0	0	11
40.0	57	321	334	43	43	0	0	16
41.0	57	313	334	44	44	0	0	22
42.0	56	313	334	44	44	0	0	28
43.0	57	313	334	46	46	0	0	32
44.0	57	313	334	50	50	0	0	33
45.0	57	321	333	54	54	0	0	33
46.0	59	313	333	58	59	0	0	33
47.0	59	313	333	61	62	0	0	32
48.0	59	313	333	62	63	0	0	29
49.0	59	313	333	62	63	0	0	27
50.0	57	313	333	62	63	0	0	27
51.0	59	313	333	62	63	0	0	27
52.0	59	313	333	62	62	0	0	27
53.0	59	321	333	63	63	0	0	28
54.0	57	313	333	64	64	0	0	29
55.0	57	313	333	64	65	0	0	29
56.0	56	313	333	65	66	0	0	29
57.0	57	313	333	66	67	0	0	29
58.0	57	313	332	67	68	0	0	30
59.0	57	313	280	68	68	0	0	30
60.0	57	313	241	68	68	0	0	29
61.0	57	313	211	69	69	0	0	30
62.0	57	313	186	69	69	0	0	30

TEST NUMBER 243.13

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
63.0	57	313	164	69	69	0	0	29
64.0	57	313	146	69	69	0	0	30
65.0	56	313	129	68	69	0	0	30
66.0	56	313	115	68	68	0	0	30
67.0	56	313	103	68	68	0	0	30
68.0	56	313	93	67	67	0	0	30
69.0	56	313	85	67	67	0	0	30

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.14
TEST DESCRIPTION NAVY TUBE UPWARD FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/35	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.14

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	56	313	12	12	13	0	0	30
-8.0	56	313	12	12	13	0	0	31
-7.0	56	313	12	12	13	0	0	30
-6.0	55	313	12	12	12	0	0	30
-5.0	55	313	12	12	13	0	0	30
-4.0	57	313	12	12	12	0	0	31
-3.0	56	313	12	12	12	0	0	30
-2.0	56	313	12	12	13	0	0	30
-1.0	55	321	12	12	13	0	0	31
0.0	56	313	13	12	13	0	0	30
1.0	55	313	335	13	14	0	0	31
2.0	57	313	335	15	15	0	0	30
3.0	56	313	335	17	18	0	0	30
4.0	56	313	334	19	20	0	0	30
5.0	59	313	334	21	21	0	0	30
6.0	56	313	334	23	24	0	0	30
7.0	57	313	334	24	25	0	0	30
8.0	59	321	333	25	25	0	0	27
9.0	57	313	333	26	26	0	0	26
10.0	57	321	333	27	27	0	0	24
11.0	57	313	333	27	28	0	0	21
12.0	56	321	333	28	29	0	0	17
13.0	57	313	333	29	29	0	0	11
14.0	57	313	333	29	29	0	0	6
15.0	57	313	333	30	31	0	0	0
16.0	59	321	333	31	31	0	0	0
17.0	57	313	333	31	32	0	0	0
18.0	59	313	333	32	32	0	0	0
19.0	57	313	333	32	33	0	0	0
20.0	56	313	333	33	34	0	0	0
21.0	57	313	333	33	34	0	0	0
22.0	56	313	333	34	35	0	0	0
23.0	56	313	333	35	35	0	0	0
24.0	57	313	333	35	35	0	0	0
25.0	56	313	333	36	35	0	0	0
26.0	57	321	333	36	36	0	0	0
27.0	56	313	333	37	37	0	0	0
28.0	56	313	333	37	37	0	0	0
29.0	56	313	333	38	38	0	0	0
30.0	57	313	333	38	39	0	0	0
31.0	56	313	333	39	39	0	0	0
32.0	57	313	333	39	39	0	0	0
33.0	57	313	333	40	40	0	0	0
34.0	56	313	333	40	40	0	0	0
35.0	56	313	333	40	41	0	0	0
36.0	56	313	333	41	41	0	0	0
37.0	56	321	333	41	42	0	0	0
38.0	56	313	333	42	42	0	0	0
39.0	55	313	333	42	42	0	0	0
40.0	56	321	333	43	43	0	0	0
41.0	56	321	333	43	43	0	0	0
42.0	55	313	333	44	44	0	0	0
43.0	56	313	333	44	44	0	0	0
44.0	56	313	333	44	45	0	0	0
45.0	56	313	333	45	45	0	0	0
46.0	56	313	333	45	45	0	0	0
47.0	55	313	333	46	46	0	0	0
48.0	56	313	333	46	46	0	0	0
49.0	56	313	333	46	46	0	0	0
50.0	55	313	332	46	47	0	0	0
51.0	55	313	328	47	47	0	0	0
52.0	55	313	301	47	48	0	0	0
53.0	56	313	278	47	48	0	0	0
54.0	55	313	259	47	48	0	0	0
55.0	55	313	243	48	48	0	0	0
56.0	55	313	227	48	48	0	0	0
57.0	54	313	213	48	48	0	0	0
58.0	55	313	200	48	48	0	0	0
59.0	55	313	188	48	48	0	0	0
60.0	55	313	176	47	48	0	0	0
61.0	54	313	166	47	48	0	0	0
62.0	54	313	156	47	48	0	0	0

TEST DATE = 02/22/85
PROGRAM ENGINEER'S NAME HOMA
TEST NUMBER 243.15
TEST DESCRIPTION NAVY TUBE UPWARD FLAME PROPAGATION TEST, CARBON STEEL TUBE

CHL.	NAME	UNITS	A0	A1	LOWER RANGE	UPPER RANGE	WSTF ID	CAL. DUE DATE	DISPLAY	STORAGE
0	TT-101	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	YES
1	TT-103	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
5	TT-115	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
6	TT-118	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
7	TT-120	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
8	PT-06	PSIG	28.1555	8.146850	0	10000	1758	06/13/85	YES	YES
9	PT-19	PSIA	.9588	.240390	0	300	1109	07/24/85	YES	YES
10	PT-28	PSIG	6.3054	8.155830	0	10000	2654	05/08/85	YES	NO
12	PT-100A	PSIA	-1.1727	.241900	0	300	1110	07/25/85	YES	YES
15	PT-126	PSIA	-3.9401	.233270	0	300	1303	07/25/85	YES	YES
17	INT.8	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
18	INT.7	VOLTS	0.0000	.002440	0	0	0	12/12/85	NO	YES
26	V.P.	DEG.	0.0000	.856300	0	90	0	12/12/90	YES	YES
38	TT-201	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
40	TT-203	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
41	TT-204	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
43	TT-208	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
45	TT-210	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO
46	TT-211	Deg.F	TYPE K (SEGMENTED)		0	0	0	0	YES	NO

PROGRAM VARIABLES STORED ON DISKETTE

TEST NUMBER 243.15

TIME SECS	TT-101 Deg.F	PT-06 PSIG	PT-19 PSIA	PT-100A PSIA	PT-126 PSIA	INT.8 VOLTS	INT.7 VOLTS	V.P. DEG.
-9.0	54	313	12	12	13	0	0	29
-8.0	54	321	12	12	13	0	0	29
-7.0	54	313	13	12	13	0	0	30
-6.0	54	313	13	12	13	0	0	30
-5.0	55	313	12	12	13	0	0	30
-4.0	55	313	13	12	13	0	0	29
-3.0	54	313	12	12	13	0	0	29
-2.0	54	313	12	12	13	0	0	30
-1.0	54	321	12	12	13	0	0	29
0.0	55	313	12	12	13	0	0	29
1.0	54	321	335	14	14	0	0	30
2.0	55	313	334	16	17	0	0	31
3.0	55	321	334	18	19	0	0	31
4.0	55	313	333	21	21	0	0	31
5.0	54	313	333	23	24	0	0	31
6.0	55	313	333	25	25	0	0	30
7.0	56	313	333	26	26	0	0	28
8.0	56	313	332	26	27	0	0	27
9.0	55	313	332	27	28	0	0	24
10.0	56	313	332	28	28	0	0	20
11.0	56	313	332	28	28	0	0	15
12.0	56	313	332	29	29	0	0	10
13.0	56	313	332	30	30	0	0	6
14.0	56	313	332	30	31	0	0	0
15.0	56	313	332	31	31	0	0	0
16.0	56	313	332	31	32	0	0	0
17.0	55	313	332	32	32	0	0	0
18.0	56	313	332	32	33	0	0	0
19.0	56	313	332	33	34	0	0	0
20.0	56	313	332	34	35	0	0	0
21.0	56	313	332	34	35	0	0	0
22.0	55	313	332	35	35	0	0	0
23.0	55	313	332	35	35	0	0	0
24.0	55	313	332	36	36	0	0	0
25.0	56	313	332	36	36	0	0	0
26.0	55	313	332	37	37	0	0	0
27.0	55	313	332	37	38	0	0	0
28.0	55	313	332	38	38	0	0	0
29.0	55	313	332	38	39	0	0	0
30.0	55	313	332	39	39	0	0	0
31.0	55	313	332	39	40	0	0	0
32.0	55	313	332	39	40	0	0	0
33.0	56	313	332	40	40	0	0	0
34.0	55	313	332	40	41	0	0	0
35.0	55	313	332	41	41	0	0	0
36.0	55	313	332	41	42	0	0	0
37.0	55	313	332	42	43	0	0	0
38.0	55	313	332	42	42	0	0	0
39.0	55	313	332	43	43	0	0	0
40.0	55	313	332	43	44	0	0	0
41.0	55	313	332	44	45	0	0	0
42.0	55	313	332	44	44	0	0	0
43.0	55	313	332	44	45	0	0	0
44.0	55	313	332	45	46	0	0	0
45.0	55	313	332	45	46	0	0	0
46.0	54	313	332	45	46	0	0	0
47.0	56	313	332	46	46	0	0	0
48.0	54	313	332	46	47	0	0	0
49.0	55	313	332	46	47	0	0	0
50.0	54	313	332	47	47	0	0	0
51.0	54	313	315	47	48	0	0	0
52.0	53	313	290	47	48	0	0	0
53.0	54	313	269	47	48	0	0	0
54.0	54	313	251	48	48	0	0	0
55.0	54	313	236	48	48	0	0	0
56.0	55	313	221	48	48	0	0	0
57.0	54	313	207	48	48	0	0	0
58.0	54	313	194	48	48	0	0	0
59.0	54	313	183	47	48	0	0	0
60.0	54	313	172	47	48	0	0	0
61.0	55	313	162	47	47	0	0	0
62.0	54	313	152	47	47	0	0	0

APPENDIX B

List of Special Equipment Used at White Sands Test Facility

Parameter Measured	WSTF Part No.	Manufacturer	Model	Range	Accuracy	Last Calibration
Inlet Press To Test Article	PT-100A	Alcino Transducers	152-BAO-89	0-300 psi	± 3 psi	02/28/84
Inlet Press to PCV	PT 19	Alcino Transducers	152-BAO-89	0-300 psi	± 3 psi	10/18/84
Outlet Press from PCV	PT 26	Alcino Transducers	152-BAO-89	0-300 psi	± 3 psi	8/7/84
Ignitor		Victor	Oxyacetelene Torch			
Propagation Rate	High Speed Video	Spin Physics	2000	60-2000 frame/sec		Set at 500 frame/sec

APPENDIX C

Calculation of Volume Flow Rates

Formula

$$\dot{Q} = \frac{(FV\ (\Delta P)\ T_{STP}}{P_{STP}\ T\quad \Delta t}$$

$\dot{Q}$ = Volume flow rate in (standard cubic feet per minute) standard litres per minute

FV = Floodable volume of cylinder

ΔP = Change in pressure of cylinder

T_{STP} = Standard temperature $70^{o}F$ (529.69 R)

P_{STP} = 14.7 psi

Δt = time in minutes for specific ΔP

$\dot{Q}_{295psi}$ = 5.43 SCFM (153.9 SLPM)

$\dot{Q}_{110psi}$ = 2.13 SCFM (60.2 SLPM)

$\dot{Q}_{60psi}$ = 1.23 SCFM (34.9 SLPM)

$\dot{Q}_{20psi}$ = 0.46 SCFM (13.2 SLPM)

Cleaning Specification

Table 4-19. Clean for Oxygen Service

SYSTEM	SUBSYSTEM	MRC CODE	
MK 15 MOD 0 Underwater Breathing Apparatus	Pneumatics Assembly	R-14	
COMPONENT	RELATED MR	RATES	M/H
Oxygen Pneumatics Components	R-16	UDT/SEAL 5321 5326	

MAINTENANCE REQUIREMENT DESCRIPTION

1. Clean tubing and associated components for oxygen service.
2. Clean valves, regulators for oxygen service
3. Clean O-rings for oxygen service.

TOTAL M/H

ELAPSED TIME

SAFETY PRECAUTIONS

1. Comply with safety precautions of the MK 15 Technical Manual. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series. Shore activities comply with Safety Precautions for Shore Activities, NAVMAT P-5100 series.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. MK 15 Technical Manual, Opn and Maint Instr, NAVSEA 0994-LP-016-1010
2. Nitrogen type II, Class I, Grade A
3. Anhydrous trisodium phosphate (TSP) NA_3PO_4 Technical grade.
4. Tube cleaning brush
5. Masking tape
6. Containment bags of nylon C or Aclar 33C
7. Filter cloth for clean rags to be disposed of after each use.
8. Fluorolube
9. Isopropyl alcohol, laboratory grade.
10. Ultrasonic cleaner
11. Cleaning solvent (Freon PCA)
12. Hot plate
13. 3 Gallon stainless steel container
14. Forceps
15. Tags

PROCEDURE

NOTE 1: If performance of this procedure involves entry into the pneumatics assembly, perform reentry control procedure as described on MRC R-16.

1. <u>Clean Tubing and Associated Components for Oxygen Service</u>.
   a. Remove all visible contaminants from each component, scrubbing with small brush and FREON (PCA). Remove rust, paint, tape glue, and grease.
   b. Prepare a solution of 1 lb. Anhydrous Trisodium Phosphate to 2.5 gallons clean freshwater. Heat to 160°F, place in ultrasonic cleaner.
   c. Place tubing in ultrasonic cleaner, operate cleaner for 30 minutes.
   d. After 30 minutes, circulate solution through tubing dipping into solution with forceps for 5 minutes.
   e. Submerge tubing into clean freshwater at 140°F for 30 minutes.
   f. After 30 minutes, circulate water through tubing dipping into water with forceps for 5 minutes.
   g. Dry tubing by purging with nitrogen.

LOCATION	DATE

Table 4-19. Clean for Oxygen Service--Continued

PROCEDURE--Continued MRC R-14

h. Upon completion of drying, cap or seal ends with plugs or blanks.
i. Hold plugs in place with tape.
j. Tag tubing "oxygen clean." Sign and date tag.

2. <u>Clean Valves, Regulators for Oxygen Service</u>.

a. Disassemble valve or regulator to smallest component.
b. Remove all visible contaminants from each component, scrubbing with small brush and Freon (PCA). Remove rust, paint, tape glue, and grease.
c. Prepare a solution, 1 lb. anhydrous trisodium phosphate to 2.5 gallons of clean freshwater. Heat to 160°F, place in ultrasonic cleaner.
d. Place parts in ultrasonic cleaner, operate cleaner for 30 minutes.
e. Rinse parts in clean freshwater at 140°F for 10 minutes.
f. Blow parts dry using nitrogen.
g. Reassemble valve or regulator using clean tools and gloves.
h. Seal parts in (2) aclar 33C or nylon (c) bags, marked oxygen clean. Sign and date label.

3. <u>Clean O-rings for Oxygen Service</u>.

a. Remove dirt and foreign matter from Kel-F O-rings using lint free cloth soaked in Freon (PCA).
b. Viton and Ethylene (propylene base) compound O-rings are submerged in clean isopropyl alcohol for 10 minutes.
c. Wipe with lint free cloth soaked in isopropyl alcohol.
d. Blow dry with nitrogen.
e. Seal O-ring into bags of aclar 33C or nylon (C).
f. Mark oxygen clean. Sign and date label.

APPENDIX E

Test Article (Typical) Composition

	Austenitic Stainless Steel AISI 316	Nickel-Copper Monel 400 % Composition	Carbon Steel (Annealed) AMS 5050 Similar to AISI 1010
C	0.08 max	0.3 max	0.15 max
Ni	10.0/14.0	63.0 min Nickel plus Cobalt	0.07
Cu		28.0-34.0	
Mn	2.0 max	2.0 max	0.31
Fe	Balance	2.5 max	Balance
S	0.03	0.024 max	0.05
Cr	16.0/18.0		0.04
Mo	2.0/3.0		0.02
P	0.045 max		0.029
Si	1.0 max	0.5 max	0.08

LIST OF REFERENCES

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3. Wegener, W., "Investigations on the Safe Flow Velocity To Be Admitted For Oxygen in Steel Pipelines", Stahl and Eisen, Vol. 84 No. 8, pp. 469-475, 1964.

4. Defense Metals Infromation Center Report 224, Ignition of Metals in Oxygen, by E.L. White and J.J. Ward, Feb 1966.

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